SCIENTIFIC AGRICULTURE

Vol. 23 AUGUST, 1943 No. 12

BREEDING SMOOTH-AWNED *DURUM* AND *VULGARE* WHEATS[1]

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[Received for publication March 29, 1943]

Smooth-awned *durum* wheats have been known since 1927 when Flaksberger (2) discovered them in Syria and Palestine. Sigfusson (9) in 1928 obtained smooth-awned *durum* segregates from a hybrid strain which was derived from the interspecific cross, Marquis × Iumillo. When Sigfusson (10) showed that this condition was determined by a single recessive factor pair, it seemed very possible that a smooth-awned *durum* wheat with good agronomic characters might be developed. Commercial varieties of durums are awned, and the removal of the barbs from the awns would be a definite improvement. Not only the *durum* but also the *vulgare* wheats would be materially improved by being made smooth-awned. Many varieties of *vulgare* wheats possess awns, and a definite preference for awned wheats exists in certain areas. If the barbs could be removed from the awns, a great deal of wheat straw would be safer for livestock and the wheat crop would be easier to handle. However, in spite of the fact that smooth-awned wheats have been known for more than 10 years, the writers are not aware of the development of any smooth-awned variety of either *durum* or *vulgare* wheat.

A number of Sigfusson's *durum* selections were grown at Saskatoon in 1935. The degree of smoothness of awn among these selections was variable, and Knowles (5) has shown that the basis for this is genetic. It was felt that the smoother-awned strains could be used in combinations with commercial *durum* varieties of Saskatchewan to develop hybrids combining both good agronomic possibilities and smooth awns. In addition, some interest was contained in the possibility of adding the smooth-awn condition to *vulgare* wheat. As a result a breeding program was initiated in 1936 to test the possibilities of achieving (1) an agronomically satisfactory variety of *durum* wheat with smooth awns and (2) a *vulgare* wheat with smooth awns. The hybrid populations were not as extensive as they might have been. The numbers of plants in segregating generations of intraspecific crosses of the durums were not large because the investigations were purposely exploratory in nature and designed to be a guide to more extensive work later, and partly because of poor germination of F_1 seeds.

Although these investigations have not progressed far enough to warrant announcement of the achievement of the objectives, it was felt that enough information had been gained to be of assistance to anyone

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attempting a similar project. Also, there is now sufficient basis for considering that smooth-awned *durum* and *vulgare* wheats of desirable agronomic value will be attained.

I. INTRASPECIFIC CROSSES

Two smooth-awned durum wheat lines, I-35-1 and I-35-4, both obtained from the late Mr. S. J. Sigfusson in 1934, were crossed with Mindum in order to obtain a high quality smooth-awned variety. Among all the Sigfusson lines these had the most desirable type of smoothness. They have been described and illustrated for awn-bearing character by Knowles (5). In both lines no barbing is present at the tip of the awns, but as the base is approached there are found a large number of very short barbs. Agronomically the lines fit Sigfusson's (10) description of his smooth-awned lines excepting that the degree of sterility is less than he indicated. The lines are rather short strawed, but in strength of straw they seem to excel other durum varieties. In I-35-1 the seed is *vulgare*-like and in I-35-4 it is small.

One cross, Mindum × I-35-1, was made in the field in 1936, and the other, I-35-4 × Mindum, was made in the greenhouse in 1938. In Table 1 the method in which the crosses were handled in subsequent generations is indicated. The cross, Mindum × I-35-1, has always been one generation ahead of the other. In 1940, when smooth-awned selections were made, Mindum × I-35-1 consisted mostly of smooth-awned plants, whereas, the other cross was mostly rough-awned. The selection of desirable types was easy in the former and difficult in the latter. However, 240 smooth-awned selections were obtained from both crosses. A severe reduction

TABLE 1.—HISTORICAL SUMMARY OF HYBRIDIZATION TO DEVELOP A SMOOTH-AWNED *durum* WHEAT

Year	Mindum × I-35-1	I-35-4 × Mindum
1936	Cross made in field	
1937	7 F_1 plants in field	
1938	800 F_2 plants in field	Cross made in greenhouse. 7 F_1 plants grown in field.
1939	274 progeny rows from single F_3 plants were grown, and 21 found to be smooth-awned. 17 of these were bulked and threshed.	About 800 F_2 plants were grown and 600 bulked and threshed.
1940	Approximately 6,000 smooth and near-smooth F_4 plants were grown. 129 single plant selections were made.	Approximately 5,000 plants of all degrees of smoothness and roughness were obtained; 111 smooth-awned plants were selected.
1941	115 lines were discarded because of a slight roughness of awn, leaving 14 lines.	104 lines were discarded because of a slight roughness of awn, leaving 7 lines.
1942	10 lines were considered worthy of yield tests in 1943.	5 lines were considered worthy of yield tests in 1943.

in the number of lines was made in 1941 mostly on the basis of roughness of awn. Finally, the number of lines from both crosses was narrowed to 15 in 1942 and these are being tested for yielding ability in 1943.

It will be noticed that very few of the selections made in 1940 remained in 1942. Most of the lines were discarded because of a slight roughness of awn. The standard of smooth-awnedness was made the same as that of the smooth-awned parents. In these breeding efforts it is felt that no compromise can be made for slightly rougher awns; the smoothest-awned wheats have a slight barbing at the base of the awn, and any increase in their number and size makes the practical value of the smooth-awn character much less. Besides awn-barbing, other characters have been kept in mind in judging the value of selections. Weakness of straw, general lack of vigour and poor seed appearance have been the reasons for discarding certain strains.

With these bases of selection in mind the performance of the selections in 1942 has been studied. Table 2 lists the data which were obtained from the hybrid nursery. A total of 15 hybrid lines from the two crosses remain, only 6 being discarded in 1942. All of these 15 lines have an awn-barbing similar to the smooth-awned parents. In strength of straw all selections but one are superior to Mindum or Pelissier. There seems to be reason for feeling that in these hybrid lines desirable combinations of good agronomic characters and smooth-awns have been achieved.

TABLE 2.—PERFORMANCE OF SMOOTH-AWNED HYBRID *durum* WHEAT LINES IN 1942

Parent or hybrid	Days to head	Days to mature	Height	Straw strength	Remarks
			cm.	%	
Mindum	59	112	131	50	
Pelissier	61	112	126	60	
I-35-1	58	112	112	86	
I-35-4	57	109	114	92	
Mindum × I-35-1					
–5	59	—	123	30	Weak straw; discard
–9	63	112	118	30	
–20	58	112	117	73	
–25	58	109	122	80	
–37	58	112	123	65	Awns slightly rough; discard.
–44	58	109	118	78	
–55	61	112	123	79	
–64	61	112	127	45	Weak straw; discard
–71	59	112	116	79	
–82	59	—	124	76	Awns slightly rough; discard
–84	59	109	126	79	
–98	62	109	130	79	
–116	61	109	131	81	
–129	61	109	123	79	
I-35-4 × Mindum					
–16	59	109	129	75	Awns slightly rough; discard
–35	58	109	129	79	
–48	61	—	131	67	Poor appearance; discard
–49	56	109	120	82	
–59	62	109	126	76	
–75	56	—	125	—	
–107	59	—	123	67	

However, a word of caution should be included. For perhaps the two most important characters of a *durum* wheat, quality and yield, there are no data available. The vigour and development of the selections have appeared equal to Mindum, and it is hoped that some of them will yield equally well. It is also hoped that some selections will compare favourably with Mindum in quality. Most lines showed in 1942 the same lustre and seed character as Mindum. However, it should be recalled that single plant selections were made in F_4 in the cross, Mindum $\times$ I-35-1, and in F_3 in I-35-4 $\times$ Mindum. These lines have been carried on without further selection. The strains each appear uniform, but it is expected that at least some of them are heterogeneous for quality and yield characters, both of which are determined by numerous genetic factors. Further selection will probably be necessary to insure sufficient uniformity of sample.

The small number of lines that have been produced with the same degree of awn barbing as the smooth-awned parents would seem to indicate that a number of factor-pairs are responsible for the inheritance of awn barbing. Knowles (5) reported that two factor-pairs, a major one and a minor one, were responsible for the difference in awn barbing between Mindum and the smooth-awned lines I-35-1 and I-35-4. In addition, he considered that auxiliary factor-pairs modified the extent of smoothness in plants that were homozygous for both factors for smooth awns. The plant breeding results verify this assumption.

To sum up: there is good reason to be optimistic about the prospect of obtaining good agronomic varieties of *durum* wheat with smooth awns. It is possible to select plants for hybrid populations that manifest the same degree of smoothness as the original smooth-awned material. Although the quality and yield characteristics of such lines are not known, there is still no indication that these characters are incompatible with smooth awns. If a breeding program is commenced with the purpose of producing smooth-awned durums possessing smut and rust resistance, relatively large hybrid populations should be grown. In the present study the large number of hybrids discarded because of insufficient awn smoothness left insufficient material for exacting selection for yield and quality.

II. INTERSPECIFIC HYBRIDIZATIONS

Because the smooth-awned *durum* wheat selections, I-35-1 and I-35-4, expressed the smallest amount of awn barbing, they were used in interspecific hybridizations with *vulgare* wheats. Five well-known *vulgare* varieties, Marquis, Reward, Garnet, Thatcher and Apex, were employed. One unnamed hybrid variety, A-277, a sister of Apex, was also used. All of the common wheats, with the exception of A-277, were awnletted (tip-awned). Awnletted wheats were not chosen as such, but it was thought advisable to use well-adapted varieties as *vulgare* parents, and most adapted varieties in Saskatchewan are awnletted.

Nine hybridizations (Table 3) were made in 1936. Unfortunately, the number of F_1 seeds was small and their germination poor. Populations with few exceptions were carried on in mass to F_3 which was grown in 1939. These populations were not large (Table 3).

In the fall of 1939 a search was made of all populations to discover any smooth-awned *vulgare* or *vulgare*-like segregates that might have occurred. In only 4 crosses (Table 3) was it possible to find plants that were smooth-awned and *vulgare*-like. No definitely smooth-awned *vulgare* plants were discovered. However, it was thought that some of the *vulgare*-like plants might yield smooth-awned segregates of more typical *vulgare*-character, therefore the progeny of the *vulgare*-like plants henceforth were carried in the pedigree manner.

TABLE 3.—POPULATIONS FROM HYBRIDIZATION BETWEEN SMOOTH-AWNED *durum* AND *vulgare* WHEATS

Cross	1936	1937	1938	1939	
	No. of F_1 plants	No. of F_1 plants	No. of F_2 plants	No. of F_3 plants	*Vulgare*-like smooth-awned plants
I-35-1 × Reward	14	6	200	2000	3
I-35-1 × Apex	39	22	640	6100‡	29
I-35-1 × Thatcher	28	13	140	1500	0*
I-35-1 × Marquis	14	1	20	800	4
I-35-1 × A 277	26	4	100	4600	16
I-35-4 × Garnet	18	5	100	1900	0†
I-35-4 × Reward	20	1	20	300	0†
I-35-4 × Apex	22	9	280	3300	0†
I-35-4 × Thatcher	25	6	100†		

* An F_4 generation was grown but no smooth-awned *vulgare* segregates were found and the cross was discarded.

† These crosses were discarded in 1938 or 1939.

‡ Awned F_2 segregates were sown in pedigree in F_3, and the remainder of the F_3 sown in mass. 24 smooth-awned plants were found in the pedigree rows and 5 in the mass plot.

The 3 selected plants from the cross, I-35-1 × Reward, were handled in the following manner. The seed from 1 plant was grown in the greenhouse in 1939–40, the crop was harvested in mass, and grown again in the field in 1940. All the progeny were rough-awned and the line was discarded. The seed from the remaining 2 plants was sown in the field in 1940. One progeny row yielded only awnletted plants and the other dwarf plants; both rows were discarded. I-35-1 × Reward then, yielded no practical results.

In the cross, I-35-1 × Marquis, besides the 4 smooth awned *vulgare*-like plants there were 5 *vulgare*-like plants that were semi-smooth awned. All 9 selections were sown in progeny rows in 1940. Only 1 smooth-awned plant was found among all the populations. Seed from this plant was sown in 1941 but the plants were too poor to harvest. This left only two crosses, I-35-1 × Apex and I-35-1 × A 277, to be used to carry on the study.

The method of handling the two remaining crosses in the period 1940–42 is indicated in Tables 4 and 5. I-35-1 × Apex is shown in outline in Table 4 and the cross I-35-1 × A 277 is shown in Table 5. Every year each population was carefully studied to determine if smooth-awned *vulgare*-like segregates were present. Only plants with these character-

istics were harvested; all *durum*-like or slightly rough-awned plants were discarded. The results from both hybridizations indicate similar situations, and these are discussed in the following paragraphs.

The numbers of smooth-awned *vulgare* or *vulgare*-like plants were always small. Each year a few more of the original selections, in the form of their surviving progeny, were discarded. There remained in 1942 the progeny of only one out of 16 original selections of I-35-1 × A 277 and only 3 out of 29 from the cross I-35-1 × Apex.

However, the proportion of smooth-awned plants in the surviving selections has steadily increased. In both crosses one progeny-row was found in 1942 that was homozygous for smooth awns and *vulgare* character.

TABLE 4.—BREEDING BEHAVIOUR OF 29 SMOOTH-AWNED *vulgare*-LIKE SELECTIONS FROM THE CROSS I-35-1 × APEX

Year	Generation	Selection work
1939	F_3	29 smooth-awned selections from mass and pedigree plots.
1940	F_4	10 progeny rows each contained a small number of smooth-awned plants, the total being 17. (19 progeny rows were discarded.)
1941	F_5	A total of 25 smooth-awned segregates were obtained from four of the original smooth-awned selections. (All th progeny of six of the original selections were discarded.)
1942	F_6	A total of 27 smooth-awned segregates and one progeny row uniform for smooth awns were obtained from three of the original selections. (The progeny of one of the original selections was discarded because it was *durum*-like.)

TABLE 5.—BREEDING BEHAVIOUR OF 16 SMOOTH-AWNED *vulgare*-LIKE SELECTIONS FROM THE CROSS I-35-1 × A-277

Year	Generation	Selection work
1938	F_3	16 smooth-awned plants saved.
1939	F_4	Progenies grown in greenhouse of F_3 plants 11 to 16 and each harvested in mass.
1940	F_4	Progenies of F_3 plants 1, 3 and 6 to 10 discarded. Seven smooth-awned segregates saved from progenies of F_3 plants 2, 4 and 5.
	F_5	Twenty smooth-awned segregates saved from progenies from mass F_4's of original F_3 plants 11 to 16.
1941	F_5	All progenies tracing to F_3 plants 1, 3 and 6 to 10 discarded.
	F_6	Progenies tracing to F_3 plants 11, 13 and 15 discarded, but nine from F_3 plants 12, 14 and 16 were saved.
1942	F_6	Progenies tracing to F_3 plants 14 and 16 were discarded. Progeny 12-3-1 of original F_3 plant 12 was bulked as uniformly smooth awned and *vulgare*-like.

Summing up the work on inter-specific crosses: Out of 20,500 F_3 plants from 9 different crosses a total of 52 somewhat *vulgare*-like plants were saved. In F_6 only two crosses remained, one, I-35-1 × A-277 being represented by a single smooth awned line and the other, I-35-1 × Apex, by 27 smooth awned segregates and one smooth awned line from 3 of the original F_3 selections. All of this F_6 material is *vulgare*-like and possesses moderate resistance to black stem rust. The bulked lines will be carried on in mass in 1943, and the single plants will be grown in progeny rows and handled in pedigree. Any plant rows that are homozygous for smooth-awns and *vulgare* character will be harvested in bulk.

To give some idea of the smoothness of awn that has been achieved, photographs (Figures 1 and 2) of typical awns, magnified 17 diameters, were taken of each of the two bulked lines and two single plant selection. In the same plates comparable photographs are presented of awn barbing

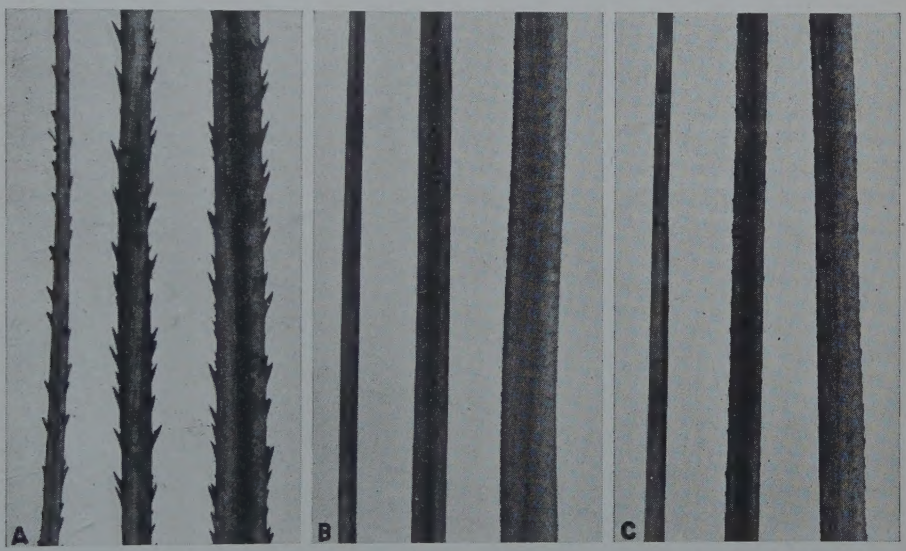

FIGURE 1. Awn barbing in wheat. Left to right on each figure the sections are from the tip, middle and base of a single awn.
A.—A 277, a rough-awned *vulgare* wheat.
B.—I-35-1, a smooth-awned *durum* wheat.
C.—A smooth-awned *vulgare* selection from the cross I-35-1 × Apex.

in A-277, a rough-awned *vulgare*-wheat, Mindum, a rough-awned durum and I-35-1, the source of smooth awns in this study. It will be seen that the degree of smoothness present in the smooth-awned durums has been successfully transferred to some *vulgare* selections; other vulgare selections (Figure 2E) show a slight barbing.

Typical heads of A-277, I-35-1, and two smooth-awned hybrid selections are given in Figure 3. The *vulgare* character of the two selections (Figure 3 C and D) together with the absence of the awn barbing (Figure 1C and 2D) on the same selections illustrates the fact that it is possible to transfer smoothness of awns from *durum* to *vulgare* wheat.

DISCUSSION

The successful transfer of the smooth awn character from the durums to vulgares was to be expected. The classical examples of the transfer of rust resistance from *T. dicoccum* to *T. vulgare* by McFadden (7) and from *T. durum* to *T. vulgare* by Hayes *et al.* (4) are too well-known to require discussion here. Harrington (3) showed that *vulgare*-like plants derived from the cross *T. dicoccum* × *T. vulgare* may possess *dicoccum*-like rust resistance or any one of 15 *dicoccum* morphologic characters. He obtained 232 fertile *vulgare*-like plants having *dicoccum* stem rust from an F_2 population of 20,000 plants. Peterson and Love (8) from a cross of Iumillo

FIGURE 2. Awn barbing in wheat. Left to right on each figure the sections are from the tip, middle and base of a single awn.
D. and E.—Smooth-awned *vulgare* selections from the cross I-35-1 × Apex.
F.—A smooth-awned *vulgare* selection from the cross I-35-1 × A-277.

durum with *vulgare* varieties, were able to establish 48 *vulgare*-like lines in F_4, F_5, or F_6, that were resistant to stem rust. Arnason (1) reported the transfer of a number of *durum* and *dicoccum* characteristics to 42-chromosome plants. The present study shows that smooth-awned character also can be transferred successfully from a 14-chromosome to a 21-chromosome wheat.

The cytology of the smooth-awned *vulgare* derivatives has not been studied. Their morphology would indicate that they are hexaploids with 42 chromosomes (2n). Studies by Thompson *et al.* (11) have shown that it is possible to transfer some *vulgare*-characters to 28-chromosome wheats, but no report is available to indicate a 28-chromosome wheat having entirely *vulgare* characteristics. However, Peterson and Love (8) found, in 48 *vulgare*-like lines from the crosses between Iumillo durum and *vulgare* varieties, that 6 lines possessed the 42-chromosome condition in all plants, 29 lines possessed some plants with 42 chromosomes, and 14 lines possessed

FIGURE 3.—Heads of wheat varieties and hybrid selections.
A.—A-277, a rough-awned *vulgare* wheat.
B.—I-35-1, a smooth-awned *durum* wheat.
C. and D.—Smooth-awned *vulgare* selections from the cross I-35-1 × Apex. (Compare with figures A, B, C and D of Figures 1 and 2 which are enlargements respectively of awns from the heads lettered A, B, C, and D in this figure.)

no plants with 42 chromosomes. Love (6) found that rust resistant *vulgare* derivatives in the fifth to seventh generation from crosses of *T. vulgare* with *T. durum* were not completely stable cytologically. Less than 42% of the plants studied had 42 chromosomes. He also found later generations, F_7 as compared with F_5, possessed less chromosome abnormality. It may be assumed then that some of the smooth-awned *vulgare* derivatives from the present study will not exhibit the usual 42 chromosome condition. However it may be expected that they will prove more stable cytologically and at the same time be more consistent in breeding behaviour as they reach later generations.

To conclude: These investigations have indicated again that it is possible to transfer a character from *durum* to *vulgare* wheats. Like previous investigations the proportion of combinations between the desired *durum* character, in this case smooth awns, and the *vulgare* appearance was extremely small. The approach to homozygous smooth-awned *vulgare* lines has been slow with only two such lines achieved by F_6. The results emphasize the need for larger populations in such studies to insure a great volume of material from which to select desirable combinations. With this in mind a further project is underway to study in more detail the transfer of smooth awns from *durum* to *vulgare* wheat.

SUMMARY

1. A program has been initiated to develop both a smooth-awned agronomically desirable *durum* and a satisfactory common bread wheat that are homozygous for smooth awns. Crosses were made between two smooth-awned durums and Mindum durum, and between the same smooth-awned durums and 6 *vulgare* varieties.

2. With respect to the achievement of suitable smooth-awned durums, considerable difficulty has been experienced in retaining a smoothness of awn equal to that of the smooth awned parent. However 15 hybrid lines have been established which are desirably smooth, and they will be given yield and quality tests in 1943.

3. It has been extremely difficult to obtain and maintain the combination of smooth awns and *vulgare* character. But in 1942 two lines were homozygous for this combination, and 27 plants from heterozygous lines have also been selected for further study.

ACKNOWLEDGMENTS

The writers acknowledge with much appreciation the assistance of Messrs. J. Whitehouse, A. G. Kusch, F. L. Quincke and M. Korol in the nursery work and the task of examining plants for their awn barbing character.

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DIGESTIBILITY STUDIES WITH SWINE

I. THE DIGESTIBILITY OF GRAINS AND CONCENTRATES AT DIFFERENT STAGES OF THE GROWING AND FATTENING PERIOD[1]

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[Received for publication April 27, 1943]

In determining coefficients of digestibility of feeds with swine, in contrast to steers, the rapid growth of the species is a factor which must be considered. When digestion trials with growing swine are conducted over a period of several months or more, the increases in weights of the animals demand increases in the amounts of the rations fed. This raises the question as to whether or not any change takes place in the digestibility of the rations due to the simultaneous increases in weights of the animals and the amounts of the rations fed. From the practical standpoint, if changes did take place, then, presumably, changes in the percentage utilization of the feeds would result. To answer the question an experiment was conducted, the results of which are reported in this paper.

In the year preceding this investigation a pilot experiment was conducted to obtain information which would act as a guide in planning the larger study. A summary of the results of this early experiment is reported in an addendum. This has been done for two reasons: (1), the results in the earlier experiment were similar to those in the later experiment; (2), barley constituted the sole ration and its coefficients could, thereby, be recorded.

The procedure for the main experiment was, in general, to conduct digestibility trials on 8 rations fed to 8 animals in 8 periods. The experiment was set up in the form of an 8 × 8 randomized latin square. The metabolism cages used are illustrated in Figure 1. The width and length are both adjustable to allow for the increase in size of animals during the trial. Each period was 21 days long, consisting of a 7-day pre-experimental sub-period, a 7-day preliminary sub-period, and a 7-day collection sub-period. At the beginning of the experiment the animals were approximately 3 months old and averaged about 40 kilograms in weight. The digestion trials were continued for 168 days. At the end of that time the average weight of the animals was approximately 140 kilograms. They were pure-bred Yorkshire pigs. In this experiment they were numbered 1 to 8, inclusively.

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The eight rations were (1) wheat, (2) corn, (3) oats, (4) middlings, (5) shorts, (6) wheat plus linseed oil meal, (7) wheat plus tankage, and (8) wheat plus white fish meal. In the mixed rations the ratio of wheat to protein supplements was 2 to 1. Supplements of Vitamins A and D, of salt, and of minerals, were given to the animals. During the pre-experimental sub-period a high protein—high mineral ration, consisting of a variety of feedstuffs, was fed for a few days.

With one exception the animals remained in good condition throughout the experiment. The exception was Animal 4 which died of acute diarrhœa at the end of Period 3. It was replaced by another pig of the same age

FIGURE 1. Metabolism Cages for Sheep and Swine.

which had been kept as a spare. The number of the animal, namely No. 4, was retained for the new pig. In addition to this, in 3 out of the 64 trials feed refusals made it impossible to obtain satisfactory coefficients of digestibility. These 3 trials were repeated at the end of Period 8 using the same animals.

As a result of all these events the data could not be examined statistically, as was originally intended, in the form of a randomized latin square. As will be seen later, however, the results for different animals and different periods were sufficiently close, so that a consideration of the data in the form of a latin square was unnecessary.

RESULTS

The complete experimental data will be found in Tables 5 to 10, inclusive, in the appendix. A summary is given in Tables 1, 2, and 3 in

the body of the text. In the appendix Tables 7 and 8 the results have been arranged to show the effect of period on the coefficients of digestibility. As originally set up, this would have been in the form of a latin square permitting the calculation of variances for ration, period, animal, and error. It was impossible, however, to estimate the three missing values in the latin square so that the data had to be considered in the form of rows and columns only. To determine the effect of period any variance due to animals was ignored, and in later tables to determine the effect of animals on the digestibility, the variance for period was not considered. The missing values in Table 7 were calculated according to the method of Yates (1).

TABLE 1.—MEAN COEFFICIENTS OF DIGESTIBILITY FOR EACH PERIOD*

Period No.	Coefficients of digestibility				
	Dry matter	Organic matter	Nitrogen	Ether extract	Total† carbohydrates
	%	%	%	%	%
1	82.4	84.6	87.2	87.0	83.2
2	83.7	85.6	89.7	86.5	84.0
3	82.4	84.4	88.4	86.2	82.9
4	81.8	84.1	86.7	85.4	83.0
5	81.5	83.9	87.5	88.6	82.2
6	81.5	83.8	87.4	84.2	82.4
7	81.8	84.0	86.9	84.8	82.6
8	81.5	83.8	87.4	81.0	82.6
Necessary difference at P of 0.05	1.2	1.0	1.6	3.5	1.1

* Each value is the mean of 8 individual values.
† Crude fibre + nitrogen-free extract.

A summary of the coefficients of Table 7, together with the necessary differences for significance, have been presented in Table 1 in the text. The estimated missing values have been included in the means shown in that table. In each case there was a statistically significant difference due to period. However, an examination of Table 1 reveals the following facts. The results for the 8 periods were reasonably constant. For instance, in the case of dry matter the necessary difference for significance was 1.2 and in only one case, namely, Period 2, was this difference found. The difference between the highest and the lowest was 2.2 and there were no significant differences between the values in Periods 1, 3, 4, 5, 6, 7, and 8. The situation was similar in the case of organic matter, nitrogen, and total carbohydrates. For ether extract two values were outside the range. Period 5 gave the highest value and Perio 8 gave the lowest value. It was quite evident then that during the growing and fattening period no appreciable change took place in the digestibility of the rations.

In Tables 9 and 10 in the appendix the data have been arranged by rations and by animals. The data for Animal 4 have been omitted in the statistical analysis given in Table 10 and in the summary given in Table 2. As stated previously, No. 4 really includes 2 animals, the first 1 having

died at the end of the third period. While the statistical analyses have been made with only 7 animals, yet if Animal 4 had been included, results

TABLE 2.—MEAN COEFFICIENTS OF DIGESTIBILITY FOR EACH ANIMAL*

Animal No.	Coefficients of digestibility				
	Dry matter	Organic matter	Nitrogen	Ether extract	Total† carbohydrates
	%	%	%	%	%
1	82.7	84.7	88.2	87.4	83.3
2	81.8	84.1	86.8	85.7	82.9
3	82.1	84.2	88.3	85.2	82.5
5	82.7	85.0	89.1	86.9	83.3
6	80.7	83.2	85.4	82.1	82.1
7	82.3	84.4	87.5	84.1	83.3
8	81.5	83.7	88.1	86.8	82.0
Necessary difference at P of 0.05	1.4	1.2	1.7	‡	‡

* Each value is the mean of 8 individual values.
† Crude fibre + nitrogen-free extract.
‡ Difference not significant.

would have been the same since values obtained for Animal 4 were close to the means for the whole 8 animals. Included in the data are the results from the 3 trials which were repeated at the end of the experiment. As in the case of the data in Table 1, so in Table 2 the results for the different animals were reasonably constant. For dry matter, organic matter, and nitrogen, statistically significant differences were found at odds of 1 to 20. No statistical differences were found for the digestibilities for ether extract and total carbohydrates. In the case of the dry matter the value for Animal 6 was lower than the rest but no statistically significant difference existed between Animals 1, 2, 3, 5, 7 and 8. In the case of organic matter the necessary difference for significance was 1.2 absolute per cent. The

TABLE 3.—COEFFICIENTS OF DIGESTIBILITY OF FEEDING STUFFS[1]

Feed	Coefficients of digestibility						
	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract	Total[2] carbo-hydrates
	%	%	%	%	%	%	%
Barley[3]	81.4	82.6	79.5	33.9	13.7	88.8	–
Wheat	90.8	91.6	92.5	80.2	23.9	94.1	91.6
Corn	90.6	91.3	86.4	86.4	36.4	93.8	92.1
Oats	69.1	–	–	–	–	–	–
Middlings	83.1	84.7	88.5	88.3	32.4	86.7	82.9
Shorts	66.9	69.1	80.3	84.8	16.9	70.4	63.5
Linseed oil meal[4]	79.2	80.9	87.2	85.3	54.9	80.9	76.4
Tankage[5]	61.8	75.3	81.2	98.2	–	–	–
Fishmeal[6]	82.2	91.1	94.5	93.9	–	–	–

[1] Each value is the mean of 8 trials.
[2] Crude fibre + nitrogen-free extract.
[3] Means of 20 values.
[4] Screw press process.
[5] 60% protein grade.
[6] White fish meal over 70% protein.

differences between the values for Animals 6 and 8, on the one hand, and the remainder on the other hand, were slightly greater than 1.0 absolute per cent. In the case of nitrogen, Animals 2 and 6 were slightly outside the range of significant difference. In all cases, however, the differences were small and it was concluded that the animals were approximately equal in their ability to digest the rations.

In Table 3 is given a summary of the coefficients of digestibility of the different feeds. In calculating the values for tankage, fish meal and linseed oil meal, the mean values for wheat obtained throughout the trials were used.

The values for oats with the exception of coefficients of dry matter have been omitted. It was suspected that the samples of oats analyzed in the laboratory were not representative of the oats as fed to the animals, since the crude fibre content was somewhat low. This fact does not affect the conclusions concerning the digestibilities of the rations in different periods or by different animals, since the oats were fed as the sole ration and not in any mixtures.

Attention can be called to the high digestibility of wheat and corn and the relatively low digestibility of oats and shorts. The coefficient of digestibility of the dry matter of the tankage is low but this is due to the large content of mineral matter which is apparently not completely absorbed. The coefficient for organic matter of tankage is considerably higher. Attention might also be called to the high digestibility of the fat in the tankage and the fish meal.

SUMMARY AND CONCLUSIONS

Eight rations were fed to 8 pigs in 8 periods through the growing and fattening period. It was concluded that no change took place in the digestibility of the rations throughout this period. It was also concluded that there were no differences between pigs in their ability to digest the various rations. Finally, coefficients of digestibility of 8 feeds for swine have been listed.

ACKNOWLEDGMENTS

Technical assistance was rendered by J. W. Kennedy, D. T. Gross and J. M. Calman.

REFERENCE

1. Goulden, C. H. Methods of Statistical Analysis. John Wiley and Sons, Inc., New York. 1939.

ADDENDUM

Digestibility of Barley

Reference was made in the introduction of the preceding paper to a preliminary experiment undertaken to serve as a guide for the main experiment. Digestibility trials were conducted on 4 registered Yorkshire pigs, all from the same litter. Barley was fed as the sole ration. At the beginning of the trials the pigs were 3 months old and averaged 37 kilograms in weight. The trials were continued in 8 periods from October, 1939, to May, 1940. At the end of that time the final weight averaged 136 kilograms. The experiment lasted 168 days, the average gain per pig per day

being 0.58 kgms. Morrison's standards were used as a guide to determine the level of feeding. Because of the unbalanced nature of barley and the difficulty experienced by the animals in consuming all of their ration, the standards were never completely met. This led to the adoption of the procedure of feeding the animals up to their maximum consumption. This amount was determined in the preliminary sub-period of each period. Between periods animals received an excellent ration of mixed grains, milling by-products, tankage and linseed oil meal, together with milk and mangels. At the end of Period 3 and through Period 4 the weather was extremely cold. All animals went off feed and experienced stiffening

TABLE 4.—SUMMARY OF COEFFICIENTS OF DIGESTIBILITY OF BARLEY

Nutrient	Animal No.	Coefficients of digestibility							
		Period numbers							Means
		1 %	2 %	3 %	5 %	6 %	7 %	8 %	%
Dry matter	5	80.3	79.8	81.0	81.5*	81.2	82.6	81.7	81.2
	6	80.9	80.4	83.7	81.4	81.0	82.0	82.4	81.7
	7	80.5	81.2*	81.8	†	–	–	–	81.2
	8	80.8	79.7	83.7	†	–	–	–	81.4
	Means	80.6	80.3	82.6	81.5	81.1	82.3	82.1	81.4
Organic matter	5	81.5	81.1	82.2	82.8	82.5	83.7	83.0	82.4
	6	82.1	81.7	84.8	82.8	82.4	83.3	83.6	83.0
	7	81.6	82.5	83.2	–	–	–	–	82.4
	8	82.1	81.0	84.9	–	–	–	–	82.7
	Means	81.8	81.6	83.8	82.8	82.5	83.5	83.3	82.6
Nitrogen	5	76.9	77.7	77.2	80.6	79.7	83.3	83.8	79.9
	6	78.4	78.2	81.8	79.6	79.5	83.0	83.9	80.6
	7	75.2	79.6	81.4	–	–	–	–	78.7
	8	75.9	74.5	80.1	–	–	–	–	76.8
	Means	76.6	77.5	80.1	80.1	79.6	83.2	83.9	79.5
Ether extract	5	33.6	16.7	36.9	45.6	22.8	20.4	57.9	33.4
	6	40.4	14.5	49.1	45.6	22.0	17.1	59.6	35.5
	7	26.8	30.1	44.7	–	–	–	–	33.9
	8	27.2	18.1	48.5	–	–	–	–	31.3
	Means	32.0	19.9	44.8	45.6	22.4	18.8	58.8	33.9
Crude fibre	5	16.0	4.6	11.5	9.5	20.1	12.8	1.8	10.9
	6	16.8	9.3	23.5	13.2	20.4	14.8	5.3	14.8
	7	17.8	13.2	12.9	–	–	–	–	14.6
	8	19.2	5.0	26.4	–	–	–	–	16.9
	Means	17.5	8.0	18.6	11.4	20.3	13.8	3.6	13.7
N-free extract	5	87.9	87.9	88.8	88.7	88.6	89.3	88.5	88.5
	6	88.3	88.6	90.1	88.5	88.8	89.1	88.8	88.9
	7	88.2	88.6	89.1	–	–	–	–	88.6
	8	88.9	87.9	90.8	–	–	–	–	89.2
	Means	88.3	88.3	89.7	88.6	88.7	89.2	88.7	88.8

* Collection period of 8 days.
† Animals removed from trial.

in the legs to a greater or less degree. They were temporarily taken off the experiment, and fed a good ration together with 10 ml. of Mead's 50% percomorph oil. At the commencement of Period 5, two animals had recovered, 2 had not. The experiment was, therefore, completed with only 2 animals. The coefficients of digestibility of barley for the 7 periods are shown in Table 4. It will be seen that the digestibility remained more or less constant throughout the growing and fattening period. Particularly noticeable was the agreement between animals.

TABLE 5.—CHEMICAL COMPOSITION OF FEEDSTUFFS

Feed	Moisture	Chemical composition of dry matter				
		Ash	Protein*	Ether extract	Crude fibre	N-free extract
	%	%	%	%	%	%
Barley	13.69	2.65	12.67	1.54	5.40	77.74
Wheat	11.62	1.95	14.88	1.97	2.79	78.41
Oats	10.89	3.01	14.23	3.90	7.91	70.95
Corn	12.88	1.55	10.41	4.47	2.49	81.08
Shorts	10.52	4.76	21.27	6.20	8.70	59.07
Middlings	10.53	3.41	20.94	5.09	4.92	65.64
Tankage	7.27	24.76	63.13	8.19	–	–
Fish meal	9.65	19.61	79.51	2.30	–	–
Linseed oil meal	9.73	5.59	34.88	8.49	8.88	42.16

* Protein factor: Barley—5.83; Wheat—5.83; Oats—5.83; Corn—6.25; Shorts, Middlings, Tankage, Fishmeal—6.25.; Linseed oil meal—5.30.

TABLE 6.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY

(Weights in Kg.; coefficients in per cent)

	Original weight	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
PERIOD I							
Animal 1							
In wheat	10.500	9.302	9.118	0.235	0.195	0.254	7.302
In feces	1.932	0.677	0.603	0.013	0.030	0.148	0.353
Coefficient		92.7	93.4	94.5	84.5	41.7	95.2
Animal 2							
In middlings	10.500	9.367	9.070	0.295	0.399	0.483	6.342
In feces	6.293	1.719	1.508	0.039	0.065	0.347	0.884
Coefficient		81.6	83.4	86.8	83.7	28.2	86.1
Animal 3							
In shorts	10.500	9.352	8.908	0.327	0.571	0.797	5.498
In feces	12.787	3.128	2.792	0.071	0.101	0.671	1.614
Coefficient		66.6	68.7	78.3	82.3	15.8	70.6
Aninal 4							
In wheat	7.000	6.201	6.078	0.156	0.130	0.169	4.868
In tankage	3.500	3.215	2.465	0.326	0.303	–	–
In total ration	10.500	9.416	8.543	0.482	0.433	0.169	4.868
In feces	4.401	1.734	1.096	0.069	0.031	0.156	0.498
Coefficient		81.6	87.2	85.7	92.8	77.1	89.8

TABLE 6.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY—*Continued*

	Original weight	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
Animal 5							
In oats	10.500	9.370	9.065	0.236	0.347	0.721	6.622
In feces	8.486	2.630	2.423	0.036	0.043	0.854	1.310
Coefficient		71.9	73.3	84.7	87.6		
Animal 6							
In corn	10.500	9.186	9.022	0.157	0.410	0.276	7.364
In feces	2.535	0.837	0.750	0.025	0.052	0.127	0.425
Coefficient		90.9	91.7	84.1	87.3	54.0	94.2
Animal 7							
In wheat	7.000	6.233	6.109	0.159	0.129	0.173	4.881
In L.O.M.	3.500	3.159	2.979	0.209	0.270	0.263	1.339
In total ration	10.500	9.392	9.088	0.368	0.399	0.436	6.220
In feces	3.791	1.184	1.040	0.039	0.048	0.249	0.525
Coefficient		87.4	88.6	89.4	88.0	42.9	91.6
Animal 8							
In wheat	7.000	6.233	6.109	0.159	0.129	0.173	4.881
In fishmeal	3.500	3.167	2.554	0.406	0.077	–	–
In total ration	10.500	9.400	8.663	0.565	0.206	0.173	4.881
In feces	2.935	1.292	0.861	0.035	0.021	0.170	0.464
Coefficient		86.3	90.1	93.8	89.8	1.7	90.5
PERIOD II							
Animal 1							
In shorts	10.500	9.457	9.005	0.324	0.604	0.850	5.526
In feces	11.704	3.044	2.730	0.057	0.080	0.684	1.647
Coefficient		67.8	69.7	82.4	86.8	19.5	70.2
Animal 2							
In wheat	12.600	11.263	11.048	0.287	0.230	0.337	8.804
In feces	2.651	0.924	0.817	0.019	0.042	0.211	0.454
Coefficient		91.8	92.6	93.4	81.7	37.4	94.8
Animal 3							
In wheat	8.400	7.509	7.366	0.192	0.153	0.225	5.870
In tankage	4.200	3.906	3.019	0.401	0.358	–	–
In total ration		11.415	10.385	0.593	0.511	0.225	5.870
In feces	3.851	1.775	1.116	0.064	0.034	0.184	0.511
Coefficient		84.5	89.3	89.2	93.3	18.2	91.3
Animal 4							
In oats	12.600	11.309	10.991	0.268	0.458	0.850	8.121
In feces	10.451	3.438	3.120	0.041	0.089	1.057	1.713
Coefficient		69.6	71.6	84.7	80.6	–	–
Animal 5							
In corn	12.600	11.063	10.893	0.186	0.500	0.304	8.927
In feces	2.343	0.895	0.802	0.020	0.060	0.135	0.482
Coefficient		91.9	92.6	89.2	88.0	55.6	94.6
Animal 7							
In wheat	8.400	7.477	7.336	0.189	0.158	0.189	5.888
In fish meal	4.200	3.827	3.079	0.492	0.080	–	–
In total ration	12.600	11.304	10.415	0.681	0.238	0.189	5.888
In feces	2.388	0.996	0.643	0.028	0.036	0.107	0.339
Coefficient		91.2	93.8	95.9	84.9	43.4	94.2
Animal 8							
In middlings	12.600	11.354	10.948	0.402	0.643	0.511	7.280
In feces	6.257	1.869	1.644	0.037	0.058	0.397	0.973
Coefficient		83.5	85.0	90.8	91.0	22.3	86.6

TABLE 6.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY—*Continued*

	Original weight	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
PERIOD III							
Animal 1							
In wheat	7.000	6.214	6.093	0.162	0.116	0.179	4.851
In L.O.M.	3.500	3.180	2.996	0.209	0.257	0.299	1.331
In total ration	10.500	9.394	0.089	0.371	0.373	0.478	6.182
In feces	3.017	1.091	0.981	0.029	0.042	0.253	0.500
Coefficient		88.4	89.2	92.2	88.7	47.1	91.9
Animal 2							
In corn	14.700	12.842	12.634	0.217	0.577	0.293	10.412
In feces	3.749	1.357	1.248	0.033	0.080	0.241	0.743
Coefficient		89.4	90.1	84.8	86.1	17.7	92.9
Animal 3							
In wheat	14.700	13.049	12.795	0.341	0.244	0.376	10.187
In feces	3.765	1.243	1.130	0.023	0.049	0.335	0.615
Coefficient		90.5	91.2	93.3	79.9	10.9	94.0
Animal 4							
In wheat	5.600	4.971	4.874	0.130	0.093	0.143	3.881
In fishmeal	2.800	2.542	2.056	0.328	0.055	–	–
In total ration	8.400	7.513	6.930	0.458	0.148	0.143	3.881
In feces	2.000	0.793	0.549	0.031	0.023	0.094	0.266
Coefficient		89.4	92.1	93.2	84.5	34.3	93.1
Animal 5							
In shorts	9.000	8.108	7.724	0.286	0.534	0.667	4.740
In feces	10.345	2.470	2.214	0.043	0.063	0.584	1.316
Coefficient	–	69.5	71.3	85.0	88.2	12.4	72.2
Animal 6							
In wheat	9.800	8.715	8.550	0.226	0.175	0.234	6.825
In tankage	4.900	4.588	3.304	0.459	0.315	–	–
In total ration		13.303	11.854	0.685	0.490	0.234	6.825
In feces	7.411	2.827	1.704	0.115	0.051	0.234	0.766
Coefficient		78.7	85.6	83.2	89.6	0	88.8
*Animal 7**							
In middlings	10.500	9.473	9.148	0.326	0.520	0.471	6.121
In feces	5.115	1.522	1.320	0.036	0.068	0.283	0.771
Coefficient		83.9	85.6	89.0	87.3	39.9	87.4
Animal 8							
In oats	14.700	13.179	12.768	0.318	0.528	1.125	9.262
In feces	13.876	4.087	3.774	0.043	0.078	1.372	2.064
Coefficient	–	69.0	70.4	86.5	85.2	–	–
PERIOD IV							
Animal 1							
In oats	12.600	11.309	10.974	0.275	0.447	0.881	8.044
In feces	9.730	3.619	3.342	0.048	0.066	1.149	1.823
Coefficient		68.0	69.5	82.5	85.2	–	–
Animal 2							
In wheat	8.400	7.489	7.336	0.195	0.158	0.219	5.821
In fishmeal	4.200	3.809	3.085	0.481	0.075	–	–
In total ration		11.298	10.421	0.676	0.233	0.219	5.821
In feces	2.843	1.331	0.871	0.045	0.045	0.150	0.423
Coefficient		88.2	91.6	93.3	80.7	31.5	92.7

* Collection period 6 days.

TABLE 6.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY—*Continued*

	Original weight	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
Animal 3							
In wheat	8.400	7.489	7.336	0.195	0.158	0.219	5.821
In L.O.M.	4.200	3.825	3.609	0.244	0.314	0.338	1.665
In total ration		11.314	10.945	0.439	0.472	0.557	7.486
In feces	4.623	1.496	1.318	0.043	0.082	0.333	0.646
Coefficient		86.8	88.0	90.2	82.6	40.2	91.4
Animal 4							
In shorts	7.200	6.510	6.200	0.215	0.390	0.594	3.877
In feces	9.636	2.155	1.888	0.045	0.064	0.464	1.100
Coefficient		66.9	69.5	79.1	83.6	21.9	71.6
Animal 5							
In wheat	16.800	14.964	14.678	0.387	0.310	0.420	11.694
In feces	3.823	1.295	1.167	0.027	0.051	0.298	0.667
Coefficient		91.3	92.0	93.0	83.5	29.0	94.3
Animal 6							
In middlings	14.700	13.236	12.824	0.404	0.525	0.761	9.012
In feces	8.638	2.186	1.925	0.056	0.061	0.422	1.141
Coefficient		83.5	85.0	86.1	88.4	44.5	87.3
Animal 7							
In corn	16.800	14.804	14.573	0.244	0.573	0.370	12.102
In feces	4.173	1.432	1.307	0.033	0.086	0.274	0.757
Coefficient		90.3	91.0	86.5	85.0	25.9	93.7
Animal 8							
In wheat	11.200	9.976	9.785	0.258	0.207	0.280	7.796
In tankage	5.600	5.248	3.835	0.515	0.386	–	–
In total ration		15.224	13.620	0.773	0.593	0.280	7.796
In feces	6.643	3.185	1.904	0.133	0.037	0.293	0.785
Coefficient		79.1	86.0	82.8	93.8	−4.6	89.9
PERIOD V							
Animal 1 Removed from Trial.							
Animal 2							
In oats	14.700	13.098	12.716	0.324	0.542	0.972	9.313
In feces	12.322	4.024	3.723	0.052	0.071	1.350	2.027
Coefficient		69.3	70.7	84.0	86.9	–	–
Animal 3							
In corn	18.900	16.458	16.219	0.265	0.787	0.425	13.357
In feces	3.877	1.419	1.312	0.031	0.077	0.341	0.710
Coefficient		91.4	91.9	88.3	90.2	19.8	94.7
Animal 4							
In wheat	18.900	16.734	16.411	0.426	0.321	0.445	13.163
In feces	5.567	1.500	1.331	0.030	0.047	0.385	0.730
Coefficient		91.0	91.9	93.0	85.4	13.5	94.5
Animal 5							
In wheat	9.800	8.713	8.546	0.218	0.145	0.235	6.896
In L.O.M.	4.900	4.450	4.199	0.296	0.385	0.387	1.859
In total ration		13.163	12.745	0.514	0.530	0.622	8.755
In feces	5.693	1.801	1.599	0.052	0.080	0.414	0.813
Coefficient		86.3	87.5	89.9	84.9	33.4	90.7

TABLE 6.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY—*Continued*

	Original weight	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
*Animal 6**							
In wheat	7.200	6.402	6.279	0.160	0.106	0.173	5.067
In fishmeal	3.600	3.276	2.590	0.405	0.072	–	–
In total ration	10.800	9.678	8.869	0.565	0.178	0.173	5.067
In feces	3.929	1.390	0.857	0.039	0.017	0.142	0.480
Coefficient		85.6	90.3	93.1	90.4	17.9	90.5
Animal 7							
In wheat	12.600	11.203	10.988	0.280	0.186	0.302	8.867
In tankage	6.300	5.863	4.352	0.588	0.435	–	–
In total ration		17.066	15.340	0.868	0.621	0.302	8.867
In feces	8.610	3.446	2.118	0.153	0.050	0.277	0.882
Coefficient		79.8	86.2	82.4	91.9	8.3	90.1
Animal 8							
In shorts	16.800	15.076	14.360	0.513	0.905	1.248	9.005
In feces	20.365	5.128	4.585	0.096	0.112	1.153	2.772
Coefficient		66.0	68.1	81.3	87.6	7.6	69.2
PERIOD VI							
Animal 1							
In wheat	12.600	11.135	10.903	0.281	0.222	0.314	8.728
In fishmeal	6.300	5.697	4.509	0.703	0.142	–	–
In total ration	18.900	16.832	15.412	0.984	0.364	0.314	8.728
In feces	4.120	1.938	1.209	0.053	0.049	0.196	0.658
Coefficient		88.5	92.2	94.6	86.5	37.6	92.5
Animal 2							
In wheat	14.000	12.372	12.115	0.313	0.246	0.349	9.697
In L.O.M.	7.000	6.320	5.983	0.420	0.567	0.550	2.639
In total ration	21.000	18.692	18.098	0.733	0.813	0.899	12.336
In feces	9.286	2.491	2.156	0.084	0.110	0.480	1.112
Coefficient		86.7	88.1	88.5	86.5	46.6	91.0
Animal 3							
In oats	21.000	18.722	18.140	0.453	0.719	1.537	13.248
In feces	17.578	6.019	5.574	0.064	0.159	1.940	3.076
Coefficient		67.9	69.3	85.9	77.9	–	–
Animal 4							
In middlings	16.800	15.016	14.551	0.472	0.709	0.703	10.191
In feces	9.390	2.436	2.150	0.053	0.080	0.486	1.289
Coefficient		83.8	85.2	88.8	88.7	30.9	87.4
*Animal 5**							
In wheat	6.400	5.668	5.565	0.142	0.105	0.169	4.464
In tankage	3.200	2.978	2.203	0.300	0.226	–	–
In total ration	9.600	8.646	7.768	0.442	0.331	0.169	4.464
In feces	3.340	1.618	0.951	0.057	0.021	0.109	0.464
Coefficient		81.3	87.8	87.1	93.7	35.5	89.6
Animal 6							
In shorts	14.700	13.192	12.548	0.442	0.838	1.178	7.781
In feces	20.382	4.612	4.106	0.100	0.158	0.956	2.437
Coefficient		65.0	67.3	77.4	81.1	18.8	68.7

* Collection period 4 days.

TABLE 6.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY—*Continued*

	Original weight	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
Animal 7							
In wheat	21.000	18.598	18.260	0.465	0.346	0.556	14.646
In feces	6.757	2.017	1.806	0.043	0.090	0.467	1.013
Coefficient		89.2	90.1	90.8	74.0	16.0	93.1
Animal 8							
In corn	21.000	18.360	17.747	0.295	0.861	0.428	14.982
In feces	5.210	1.895	1.703	0.040	0.129	0.277	1.060
Coefficient		89.7	90.4	86.4	85.0	35.3	92.9
PERIOD VII							
Animal 1							
In wheat	14.000	12.331	12.098	0.316	0.258	0.324	9.679
In tankage	7.000	6.389	5.178	0.674	0.667	–	–
In total ration	21.000	18.720	17.276	0.990	0.925	0.324	9.679
In feces	7.930	3.533	2.325	0.161	0.078	0.324	0.951
Coefficient		81.1	86.5	83.7	91.6	0	90.2
Animal 2							
In shorts	18.900	16.897	16.101	0.559	1.043	1.527	10.039
In feces	24.527	5.641	4.991	0.120	0.129	1.218	2.980
Coefficient		66.6	69.0	78.5	87.6	20.2	70.3
Animal 3							
In wheat	14.000	12.331	12.098	0.316	0.258	0.324	9.679
In fishmeal	7.000	6.283	5.101	0.814	0.155	–	–
In total ration	21.000	18.614	17.199	1.130	0.413	0.324	9.679
In feces	6.100	2.441	1.593	0.075	0.053	0.258	0.853
Coefficient		86.9	90.7	93.4	87.2	20.4	91.2
Animal 4							
In corn	21.000	18.281	17.992	0.296	0.817	0.413	14.908
In feces	5.877	1.861	1.684	0.045	0.141	0.268	1.009
Coefficient		89.8	90.6	84.8	82.7	35.1	93.2
Animal 5							
In middlings	18.900	16.821	16.231	0.584	0.930	0.838	10.811
In feces	11.625	2.910	2.532	0.061	0.094	0.589	1.514
Coefficient		82.7	84.4	89.6	89.9	29.7	86.0
Animal 6							
In wheat	21.000	18.478	18.094	0.464	0.331	0.508	14.550
In feces	7.743	1.954	1.742	0.050	0.085	0.399	0.985
Coefficient		89.4	90.4	89.2	74.3	21.5	93.2
Animal 7							
In oats	16.200	14.322	13.908	0.352	0.566	1.063	10.226
In feces	13.968	4.334	4.001	0.049	0.107	1.413	2.224
Coefficient		69.7	71.2	86.1	81.1	–	–
Animal 8							
In wheat	14.000	12.319	12.063	0.309	0.221	0.339	9.700
In L.O.M.	7.000	6.298	5.956	0.414	0.555	0.534	2.674
In total ration		18.617	18.019	0.723	0.776	0.873	12.374
In feces	7.468	2.271	1.998	0.071	0.127	0.455	1.017
Coefficient		87.8	88.9	90.2	83.6	47.9	91.8
PERIOD VIII							
Animal 1							
In corn	18.000	15.615	15.395	0.265	0.689	0.373	12.672
In feces	3.874	1.378	1.249	0.035	0.090	0.195	0.762
Coefficient		91.2	91.9	86.8	86.9	47.7	94.0

TABLE 6.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY—*Concluded*

	Original weight	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
Animal 2							
In wheat	14.000	12.289	12.044	0.319	0.247	0.331	9.604
In tankage	7.000	6.459	4.746	0.641	0.469	–	–
In total ration	21.000	18.748	16.790	0.960	0.716	0.331	9.604
In feces	8.079	3.652	2.169	0.147	0.052	0.279	0.907
Coefficient		80.5	87.1	84.7	92.7	15.7	90.6
Animal 3							
In middlings	18.900	16.881	16.267	0.595	0.977	0.748	10.816
In feces	9.906	2.951	2.585	0.072	0.113	0.559	1.510
Coefficient		82.5	84.1	87.9	88.4	25.3	86.0
Animal 4							
In wheat	10.800	9.480	9.291	0.246	0.191	0.255	7.409
In L.O.M.	5.400	4.839	4.565	0.320	0.414	0.457	2.001
In total ration	16.200	14.319	13.856	0.566	0.605	0.712	9.410
In feces	7.290	1.906	1.664	0.061	0.144	0.390	0.790
Coefficient		86.7	88.0	89.2	76.2	45.2	91.6
*Animal 5**							
In wheat	6.400	5.599	5.497	0.144	0.111	0.151	4.394
In fishmeal	3.200	2.833	2.290	0.365	0.073	–	–
In total ration		8.432	7.787	0.509	0.184	0.151	4.394
In feces	2.475	1.102	0.716	0.031	0.038	0.104	0.377
Coefficient		86.9	90.8	93.9	79.3	31.1	91.4
Animal 6†							
In oats	12.000	10.540	10.226	0.259	0.377	0.914	7.428
In feces	11.493	3.436	3.175	0.042	0.126	1.101	1.717
Coefficient		67.4	69.0	83.8	66.6	–	–
Animal 7 Results discarded							
Animal 8‡							
In wheat	12.000	10.498	10.307	0.270	0.209	0.282	8.239
In feces	3.129	1.034	0.936	0.020	0.046	0.222	0.554
Coefficient		90.2	90.9	92.6	78.0	21.3	93.3
PERIOD IX							
*Animal 1**							
In middlings	8.400	7.435	7.156	0.258	0.396	0.364	4.782
In feces	3.934	1.223	1.069	0.028	0.044	0.224	0.647
Coefficient		83.6	85.1	89.1	88.9	38.5	86.5
Animal 6							
In wheat	12.600	10.965	10.747	0.279	0.221	0.297	8.601
In L.O.M.	6.300	5.612	5.304	0.371	0.453	0.501	2.387
In total ration		16.577	16.051	0.650	0.674	0.798	10.988
In feces	10.118	2.501	2.183	0.088	0.139	0.470	1.096
Coefficient		84.9	86.4	86.5	79.4	41.1	90.0
Animal 7							
In shorts	16.800	14.833	14.130	0.506	0.896	1.289	8.786
In feces	21.636	4.916	4.387	0.101	0.172	1.040	2.619
Coefficient		66.9	69.0	80.0	80.8	19.3	70.2

* Collection period 4 days. † Collection period 5 days. ‡ Collection period 5 days.

TABLE 7.—SUMMARY OF COEFFICIENTS OF DIGESTIBILITY OF RATIONS AS FED ARRANGED BY PERIODS AND BY RATIONS (ESTIMATED MISSING VALUES IN BRACKETS)

Period	Wheat	Oats	Corn	Shorts	Mid-dlings	Wheat + tankage	Wheat + fish meal	Wheat + linseed oil meal	Means*
	%	%	%	%	%	%	%	%	%
Dry matter									
1	92.7	71.9	90.9	66.6	81.6	81.6	86.3	87.4	82.4
2	91.8	69.6	91.9	67.8	83.5	84.5	91.2	(89.0)	82.9
3	90.5	69.0	89.4	69.5	83.9	78.7	89.4	88.4	82.4
4	91.3	68.0	90.3	66.9	83.5	79.1	88.2	86.8	81.8
5	91.0	69.3	91.4	66.0	(82.4)	79.8	85.6	86.3	81.3
6	89.2	67.9	89.7	65.0	83.8	81.3	88.5	86.7	81.5
7	89.4	69.7	89.8	66.6	82.7	81.1	86.9	87.8	81.8
8	90.2	67.4	91.2	(66.2)	82.5	80.5	86.9	86.7	83.6
Means	90.8	69.1	90.6	66.9	83.1	80.8	87.9	87.2	82.2
Organic matter									
1	93.4	73.3	91.7	68.7	83.4	87.2	90.1	88.6	84.6
2	92.6	71.6	92.6	69.7	85.0	89.3	93.8	(89.8)	84.9
3	91.2	70.4	90.1	71.3	85.6	85.6	92.1	89.2	84.4
4	92.0	69.5	91.0	69.5	85.0	86.0	91.6	88.0	84.1
5	91.9	70.7	91.9	68.1	(84.2)	86.2	90.3	87.5	83.8
6	91.1	69.3	90.4	67.3	85.2	87.8	92.2	88.1	83.8
7	90.4	71.2	90.6	69.0	84.4	86.5	90.7	88.9	84.0
8	90.9	69.0	91.9	(68.5)	84.1	87.1	90.8	88.0	86.0
Means	91.6	70.6	91.3	69.1	84.7	87.0	91.5	88.3	84.4
Nitrogen									
1	94.5	84.7	84.1	78.3	86.8	85.7	93.8	89.4	87.2
2	93.4	84.7	89.2	82.4	90.8	89.2	95.9	92.3	89.4
3	93.3	86.5	84.8	85.0	89.0	83.2	93.2	92.2	88.4
4	93.0	82.5	86.5	79.1	86.1	82.8	93.3	90.2	86.7
5	93.0	84.0	88.3	81.3	(88.3)	82.4	93.1	89.9	87.4
6	90.8	85.9	86.4	77.4	88.8	87.1	94.6	88.5	87.4
7	89.2	86.1	84.8	78.5	89.6	83.7	93.4	90.2	86.9
8	92.6	83.8	86.8	(79.9)	87.9	84.7	93.9	89.2	88.7
Means	92.5	84.8	86.4	80.3	88.4	84.9	93.9	89.9	87.7
Ether extract									
1	84.6	87.6	87.3	82.3	83.7	92.8	89.8	88.0	87.0
2	81.7	80.6	88.0	86.8	91.0	93.3	84.9	(85.5)	86.6
3	79.9	85.2	86.1	88.2	87.3	89.6	84.5	88.7	86.2
4	83.5	85.2	85.0	83.6	88.4	93.8	80.7	82.6	85.4
5	85.4	86.9	90.2	87.6	(91.8)	91.9	90.4	84.9	88.2
6	74.0	77.9	85.0	81.1	88.7	93.7	86.5	86.5	84.2
7	74.3	81.1	82.7	87.6	89.9	91.6	87.2	83.6	84.8
8	78.0	66.6	86.9	(80.2)	88.4	92.7	79.3	76.2	81.2
Means	80.2	81.4	86.4	85.3	88.2	92.4	85.4	84.4	85.4
Total carbohydrates									
1	93.4	70.5	92.8	63.7	82.0	87.0	87.5	88.4	83.2
2	92.7	69.1	93.3	63.5	82.4	88.6	92.7	(89.3)	83.2
3	91.0	66.9	90.8	64.9	84.0	85.8	91.1	88.7	82.9
4	92.0	66.7	91.7	65.0	84.0	86.7	90.5	87.7	83.0
5	91.8	67.2	92.4	61.7	(82.1)	87.4	88.1	86.9	82.2
6	90.3	65.9	91.3	62.1	83.7	87.6	90.6	88.0	82.4
7	90.8	67.8	91.7	63.7	81.9	87.3	88.9	88.9	82.6
8	90.9	66.2	92.7	(63.2)	82.1	88.1	89.4	88.3	85.4
Means	91.6	67.5	92.1	63.5	82.9	87.3	89.9	88.1	83.1

* Exclusive of estimated values. Values in Table 1 are inclusive of estimated values.

TABLE 8.—ANALYSIS OF VARIANCE* OF COEFFICIENTS OF DIGESTIBILITY IN TABLE 7

Nutrient	Variance due to	D/F	Sums of squares	Variance	$\frac{1}{2}\log_e$ variance	z	Necessary difference
Dry matter	Period	7	27.76	3.966	0.6889	0.493	1.2
	Ration	7	4606.19	658.027	3.2446	3.049	
	Error	46	68.06	1.480	0.1960		
	Total	60	4702.01				
Organic matter	Period	7	17.66	2.523	0.4627	0.458	1.0
	Ration	7	4506.91	643.844	3.2337	3.229	
	Error	46	46.45	1.010	0.0050		
	Total	60	4571.02				
Nitrogen	Period	7	48.92	6.989	0.9722	0.495	1.6
	Ration	7	1061.39	151.627	2.5107	2.034	
	Error	46	119.35	2.595	0.4768		
	Total	60	1229.66				
Ether extract	Period	7	250.98	35.854	1.7897	0.536	3.5
	Ration	7	812.48	116.069	2.3771	1.123	
	Error	46	564.80	12.278	1.2539		
	Total	60	1628.26				
Total carbohydrates	Period	7	14.53	2.076	0.3652	0.2426	1.1
	Ration	7	6532.47	933.210	3.4193	3.297	
	Error	46	58.77	1.278	0.1226		
	Total	60	6605.77				

* z at $n = 7$; $n_2 = 46$ for P of $0.05 = 0.400$.

TABLE 9.—SUMMARY OF COEFFICIENTS OF DIGESTIBILITY ARRANGED BY ANIMALS AND BY THE RATIONS AS FED

Animal No.	Wheat	Oats	Corn	Shorts	Middlings	Wheat + tankage	Wheat + fishmeal	Wheat + linseed oil meal	Means
	%	%	%	%	%	%	%	%	
Dry matter									
1	92.7	68.0	91.2	67.8	83.6	81.1	88.5	88.4	82.7
2	91.8	69.3	89.4	66.6	81.6	80.5	88.2	86.7	81.8
3	90.5	67.9	91.4	66.6	82.5	84.5	86.9	86.8	82.1
4	91.0	69.6	89.8	66.9	83.8	81.6	89.4	86.7	82.4
5	91.3	71.9	91.9	69.5	82.7	81.3	86.9	86.3	82.7
6	89.4	67.4	90.9	65.0	83.5	78.7	85.6	84.9	80.7
7	89.2	69.7	90.3	66.9	83.9	79.8	91.2	87.4	82.3
8	90.2	69.0	89.7	66.0	83.5	79.1	86.3	87.8	81.5
Means	90.8	69.1	90.6	66.9	83.1	80.8	87.9	86.9	82.0
Organic matter									
1	93.4	69.5	91.9	69.7	85.1	86.5	92.2	89.2	84.7
2	92.6	70.7	90.1	69.0	83.4	87.1	91.6	88.1	84.1
3	91.2	69.3	91.9	68.7	84.1	89.3	90.7	88.0	84.2
4	91.9	71.6	90.6	69.5	85.2	87.2	92.1	88.0	84.5
5	92.0	73.3	92.6	71.3	84.4	87.8	90.8	87.5	85.0
6	90.4	69.0	91.7	67.3	85.0	85.6	90.3	86.4	83.2
7	90.1	71.2	91.0	69.0	85.6	86.2	93.8	86.6	84.4
8	90.9	70.4	90.4	68.1	85.0	86.0	90.1	88.9	82.7
Means	91.6	70.6	91.3	69.1	84.7	87.0	91.5	88.1	84.2
Nitrogen									
1	94.5	82.5	86.8	82.4	89.1	83.7	94.6	92.2	88.2
2	93.4	84.0	84.8	78.5	86.8	84.7	93.3	88.5	86.8
3	93.3	85.9	88.3	78.3	87.9	89.2	93.4	90.2	88.3
4	93.0	84.7	84.8	79.1	88.8	85.7	93.2	89.2	87.3
5	93.0	84.7	89.2	85.0	89.6	87.1	93.9	89.9	89.1
6	89.2	83.8	84.1	77.4	86.1	83.2	93.1	86.5	85.4
7	90.8	86.1	86.5	80.0	89.0	82.4	95.9	89.4	87.5
8	92.6	86.5	86.4	81.3	90.8	82.8	93.8	90.2	88.1
Means	92.5	84.8	86.4	80.3	88.5	84.9	93.9	89.5	87.6
Ether extract									
1	84.6	85.2	86.9	86.8	88.9	91.6	86.5	88.7	87.4
2	81.7	86.9	86.1	87.6	83.7	92.7	80.7	86.5	85.7
3	79.9	77.9	90.2	82.3	88.4	93.3	87.2	82.6	85.2
4	85.4	80.6	82.7	83.6	88.7	92.8	84.5	76.2	84.3
5	83.5	87.6	88.0	88.2	89.9	93.7	79.3	84.9	86.9
6	74.3	66.6	87.3	81.1	88.4	89.6	90.4	79.4	82.1
7	74.0	81.1	85.0	80.8	87.3	91.9	84.9	88.0	84.1
8	78.0	85.2	85.0	87.6	91.0	93.8	89.8	83.6	86.8
Means	80.2	81.4	86.4	84.8	88.3	92.4	85.4	83.7	85.3
Total carbohydrates									
1	93.4	66.7	92.7	63.5	83.1	87.3	90.6	88.7	83.3
2	92.7	67.2	90.8	63.7	82.0	88.1	90.5	88.0	82.9
3	91.0	65.9	92.4	63.7	82.1	88.6	88.9	87.7	82.5
4	91.8	69.1	91.7	65.0	83.7	87.0	91.1	88.3	83.5
5	92.0	70.5	93.3	64.9	81.9	87.6	89.4	86.9	83.3
6	90.8	66.2	92.8	62.1	84.0	85.8	88.1	86.7	82.1
7	90.3	67.8	91.7	63.7	84.0	87.4	92.7	88.4	83.3
8	90.9	66.9	91.3	61.7	82.4	86.7	87.5	88.9	82.0
Means	91.6	67.5	92.1	63.5	82.9	87.3	89.9	88.0	82.8

TABLE 10—STATISTICAL ANALYSIS* OF DATA IN TABLE 9 (OMITTING ANIMAL NO. 4)

Nutrient	Variance due to	D/F	Sums of squares	Variance	$\frac{1}{2}\log_e$ variance	z to error	Necessary difference
Dry matter	Animal	6	25.41	4.24	0.722	0.466	1.4
	Ration	7	4243.45	606.21			
	Error	42	70.20	1.67	0.256		
	Total	55	4339.06				
Organic matter	Animal	6	16.73	2.79	0.513	0.447	1.2
	Ration	7	4183.90	597.70			
	Error	42	48.05	1.14	0.066		
	Total	55	4248.68				
Nitrogen	Animal	6	69.29	11.55	1.223	0.771	1.7
	Ration	7	961.90	137.41			
	Error	42	103.61	2.47	0.452		
	Total	55	1134.80				
Ether extract	Animal	6	163.35	27.23	1.652	0.342	†
	Ration	7	772.59	110.37			
	Error	42	576.89	13.74	1.310		
	Total	55	1512.83				
Total carbohydrates	Animal	6	14.86	2.48	0.454	0.346	†
	Ration	7	6141.82	877.40			
	Error	42	52.10	1.24	0.108		
	Total	55	6208.78				

* Necessary z for $n_1 = 6$; $n_2 = 42$, at P of 0.05 = 0.423.
† Not significant.

THE DIGESTIBILITY OF TYPICAL EASTERN CANADIAN FEEDS BY MARKET BACON HOGS. II.

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[Received for publication May 12, 1943]

In a previous paper from this laboratory (1) coefficients of digestibility for the 5 proximate principles of a typical protein-mineral supplement used to balance the grain ration of bacon hogs were presented. In another report (2) a modification of the standard Henneburg scheme of feedingstuffs analysis was proposed and the digestibility of the fractions of the same protein-mineral supplement isolated in this procedure reported. This paper presents the results of digestion trials conducted during 1942.

EXPERIMENTAL

Four series of digestion and nitrogen balance tests were conducted involving 4 basal feeds, with 4 pigs on each feed at each of 4 different weights according to the plan below.

Table 1.—Plan of digestion trials showing periods when each of the pigs was on the different rations

Rations	First test 50 lb. pigs	Second test 100 lb. pigs	Third test 150 lb. pigs	Fourth test 200 lb. pigs
No. 3 feed barley*	1**	2	3	4
No. 1 wheat screenings	2	3	4	1
No. 1 feed oats	3	4	1	2
Light oats	4	1	2	3

* Rations consisted of 85% of the basal feed plus 15% of the protein-mineral supplement. See Table 2.
** Figures are the pig numbers.

This plan made it possible to obtain data on the effect of size of pig (or age) on their ability to digest food as well as to measure the digestibility of the different feeds. The 4 Yorkshire barrows were half brothers. From weaning time to the first test, and in the intervals between tests they were fed a ration consisting of 85% No. 3 feed barley plus 15% of the same protein-mineral supplement used in the tests. The first test started for each pig when he reached a weight of 50 pounds. A 5-day preliminary

Contribution from the Faculty of Agriculture, McGill University, Macdonald College, Que., Canada. Journal Series No. 182.

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period was employed to get the pigs accustomed to the test ration and to adjust their feed intake to an amount which they would readily clean up. It was fed 3 times daily as a slop made by adding to each pound of feed, 3 pounds of water. During the subsequent 10-day collection period the daily feed intake was held constant, though the collections were actually "marker to marker". Ferric oxide fed in the first feed of the collection period and in the first feed after the 10th day proved very satisfactory for this purpose.

Twenty-four-hour collections of urine were made during the feces collection period and $\frac{1}{100}$ daily aliquots combined for the 10-day composite sample. This was preserved under toluene and H_2SO_4 to the end of the period when nitrogen determinations were made by the Kjehdahl method.

At the conclusion of first digestion test, the pigs were returned to individual pens in the piggery and fed until they reached the weight specified for the second test. Subsequent tests were conducted in the same manner excepting that during the last two, feeding was done but twice daily.

As above mentioned, the same protein-mineral supplement was used in all tests. It consisted of 25 parts meat meal, 40 parts linseed oilmeal, 15 parts fish meal, 10 parts bone char, 5 parts ground limestone and 5 parts salt. Its analysis and digestibility, established in 1941 tests (1), (2) are shown in Table 2.

TABLE 2.—CHEMICAL ANALYSIS AND DIGESTIBILITY OF THE PROTEIN-MINERAL SUPPLEMENT

Feed fraction	Composition	Digestibility
	%	%
Moisture	8.5	—
Dry matter	91.5	43
Protein (N × 6.25)	34.3	71
Ether extract	5.7	100
Ash	27.7	—
Crude fibre (Weende)	5.3	37
N-free extract (by difference)	18.5	0
Cellulose	4.0	32
Soluble carbohydrate	3.6	8
"Lignin" (by difference)	16.2	15

The composition of the 4 basal feeds whose digestibility was determined in these tests is given in Table 3.

TABLE 3.—CHEMICAL COMPOSITION OF THE BASAL FEEDS STUDIED

Fraction	No. 3 feed barley	No. 1 wheat screenings	No. 1 feed oats	Light oats
Moisture	14.5	13.5	13.5	12.0
Protein (N × 6.25)	13.1	12.7	12.8	6.5
Ether extract	1.4	2.1	2.8	1.7
Ash	2.4	1.8	3.2	5.1
Carbohydrate				
Crude fibre	5.2	5.8	10.7	25.4
N-free extract (by difference)	63.4	64.1	57.0	49.5
Carbohydrate*				
Cellulose	4.4	4.3	9.7	23.4
Soluble carbohydrate	61.6	59.2	53.8	42.2
Lignin (by difference)	2.6	6.4	4.2	9.1

* Scheme of analysis for carbohydrate proposed by Crampton and Whiting (2).

RESULTS

In obtaining the digestibility of the 4 basal feeds the following general formula was used:

$$Cx = \frac{(0.85)R - [F - R\,(0.15)\,(1.00 - Cy)]}{(0.85)R}$$

when,

C = proportion (i.e. decimal fraction) of feed or feed constituent (x), or of supplement or supplement constituent (y) digested.

R and F = weight of total ration or ration constituent (R), eaten or feces constituent (F) produced.

The values for Cy, the digestibility of the constituents (i.e. protein, ether extract, etc.) of the supplement are those shown in Table 2.

This method is the so called "difference method" of obtaining digestibility of one part of a ration. In this case it assumes that the amount of feces belonging to the supplement of the diet may be estimated from the known intake of supplement and its digestibility. This assumption is in error to whatever extent there is actually any change in the digestibility of the supplement through being fed in combination with the basal feed. Since, however, the digestibility for the supplement was initially determined by partial regression from feeding in mixed rations together with the fact that it is but 15% of the diet fed, it is believed the actual error involved is small and of no practical consequence.

TABLE 4.—COEFFICIENTS OF DIGESTIBILITY BY SWINE OF FIVE BASAL FEEDS

Feed fraction	No. 1 feed barley	No. 3 feed barley	No. 1 wheat screenings	No. 1 feed oats	Sample light oats
Dry matter	77	75	68	64	26
Organic matter	77	76	73	69	24
Protein (N × 6.25)	71	78(79)	80	89(78)	66(73)
Ether extract	13	−14(80)	27	63(88)	35(73)
Carbohydrate[1]					
Crude fibre	15	0(56)	2	9(38)	6(40)
N-free extract (by difference)	84	84(92)	80	76(81)	27(46)
Carbohydrate[2]					
Cellulose	15	−5	7	11	7
Soluble carbohydrate	86	86	86	80	30
Lignin (by difference)	19	7	2	−7	8
Digestible crude protein	10.0	10.2(9.3)	10.2	11.4(9.4)	4.3(4.0)
Total digestible nutrients[1]	66	64(79)	63	60(72)	20(43)
Total digestible nutrients[2]	65	64	63	59	20

Total Digestible Nutrients[1] = Sum of digestible protein, fibre, nitrogen-free extract, and 2.25 × digestible ether extract.
Total Digestible Nutrients[2] = Sum of digestible protein, cellulose, soluble carbohydrates, and 2.25 × digestible ether extract.
Figures in parenthesis are digestion coefficients on comparable feeds from cattle tests.

At this point it may be noted that in these tests as in those of the previous year no difference traceable to age was found in the ability of pigs to digest their ration. Therefore the data for the 4 weight groups were combined in calculating the final digestion coefficients.

In Table 4 are given the coefficients of digestion and the calculated total digestible nutrients for the 4 basal feeds involved in this study. Included also are the data for No. 1 feed barley determined under comparable conditions in the previous tests (1).

Before discussing the differences in the digestibility of these grains it will be well to present the data relative to the usefulness of the protein which they provide. The figures are given in Table 5.

TABLE 5.—PERCENTAGE OF NITROGEN FROM THE 4 RATIONS WHICH WAS DIGESTED RETAINED AND EXCRETED BY PIGS

Rations*	Nitrogen digested	Digested nitrogen which was retained in body	Total nitrogen of ration which was excreted in urine
	%	%	%
No. 3 barley	75	43	43
Screenings	78	38	49
Feed oats	83	33	56
Light oats	69	3	67

* 85% of the basal feed shown plus 15% of Protein Supplement.

DISCUSSION

In examining the figures in Table 4 it will be seen that in so far as the carbohydrates are concerned two schemes of partition were used. In general crude fibre may be expected to be largely (90% or more) cellulose and hence the digestibility of these fractions should be nearly the same. In the case of these basal feeds the lignin content is low. Therefore the nitrogen-free extract will be largely composed of soluble carbohydrates. Accordingly the digestibility of these fractions should be parallel, with that for "soluble carbohydrate" (see carbohydrate[2]) slightly higher. This also is found to be the case.

The digestibility of the "lignin" component is low, comparing closely with that of cellulose and crude fibre. This component is undoubtedly a mixture, consisting mostly, however, of lignin plus the cumulated errors in the estimation of the other fractions. It is interesting to note that its omission from the calculation of the total digestible nutrients (2) does not appear to be significant.

The apparent digestibility of the ether extract differs rather widely between the different feeds. This is in part an expression of larger error in calculated digestibility for nutrients making up but a small proportion of the total diet. Probably of greater importance, however, is the complication of metabolic fat which with pigs may amount to one-quarter or more of the total ether extract in the feces. Thus the true digestibility of this component would be considerably higher than the figure shown. Though probably a minor factor with feeds of this type, one must also bear in mind that ether extract may contain relatively little tri-glyceride, and that the residue is known to be poorly digested.

The utilization of the protein of these feeds deserves special note. It appears that digestibility of the protein of barley and screenings rations is similar, with that of good oats somewhat higher. The light weight oats ration, however, is not well digested presumably due to its high fibre content. One might expect this difference to be reflected in gains of the pigs. However, when the urinary excretion of nitrogen is taken into account it is found that less of either the dietary protein or of the digested part of the intake is retained in the body in the case of oats rations as compared to barley or wheat screenings rations. It seems evident then that though sometimes more digestible, the biological value of the oat protein is below that of barley and screenings, when fed in rations supplemented with tankage and fishmeal proteins.

Attention is also called to the comparison in the digestibility of three of these feeds by swine, and in the calculated digestible crude protein and total digestible nutrients of the feeds for swine, and corresponding figures (shown in parenthesis in Table 4) as determined with cattle. No feeds comparable to our Canadian No. 1 feed barley were available for comparison. It is evident that the digestibility of the other three grains by cattle is considerably higher than can be counted on with swine. The difference is largely accounted for by the relative inability of pigs to utilize fibre (or cellulose) and ether extract. These figures serve to further

emphasize the fact that the usefulness of feeds for swine may differ considerably from their value for cattle, and that estimates of digestible nutrients through the use of digestion coefficients applicable to cattle are likely to be 20% or more too high.

Finally, mention may be made of the two plans of partitioning the carbohydrate. As measured by digestibility, it seems to us that the isolation of cellulose and soluble carbohydrate by direct chemical procedures, and of "lignin" by difference is as useful as an index feeding value, as is the crude fibre-nitrogen-free extract partition. The two major parts are more nearly biological (and perhaps also chemical) units than is usually true with those of the Henneberg analysis plan, while the fraction left for estimation by difference, "lignin", is small as compared to nitrogen-free extract.

SUMMARY

Digestion coefficients are reported for samples of No. 1 and No. 3 feed barley, No. 1 recleaned wheat screenings, No. 1 feed oats and a sample of light weight oats.

No differences due to age or size of pig in their ability to digest food were found.

Pigs appear to be able to digest protein from basal feeds to about the same extent as is reported for cattle. The fibrous parts of the carbohydrates, however, are but poorly if at all utilized.

In general, calculated total digestible nutrients for the basal feeds of these tests may be expected to be at least 20% too high for swine if estimated by using digestibility coefficients applicable to cattle.

Partition of the carbohydrates into cellulose, soluble carbohydrate and "lignin" by the plan proposed by Crampton and Whiting (1) appears to be as useful, practically, in describing the value of a feed or ration as does the crude fibre-nitrogen-free extract plan. It has the advantage of isolating fractions more nearly approaching chemical and biological units, and of leaving a relatively small constituent, "lignin", to be determined by difference.

ADDENDUM

Description of feeds

No. 1 Feed Barley. The first grade of Canadian western barley of feed grade. It weighed 49 lb. per bushel and was practically free of weed seeds or other grain.

No. 3 Feed Barley. The third grade of Canadian feed barleys. Weight per bushel, 46 lb. It consisted of 85% barley, 2% wild oats, 10% tame oats, 2% wheat and 1% weed seeds, chiefly wild buckwheat.

No. 1 Wheat Screenings. Canadian standard recleaned wheat screenings. Weight per bushel, 50 lb. It consisted of 60% broken wheat and 40% wild buckwheat.

No. 1 Feed Oats. First grade of the feed oats. Weight per bushel, 36 lb. It consisted of 94% tame oats, 2% wild oats, 2% wheat, and 2% barley.

Sample Light Oats. A low grade light weight oat sample. Weight per bushel, 17 lb., made up of 15% wild oats and 85% poorly filled tame oats.

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LINSEED OIL MEAL REPLACING MEAT MEAL IN RATIONS FOR GROWING CHICKS[1]

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[Received for Publication March 15, 1943]

The feeding of linseed oil meal to various classes of live stock has been practiced with apparent success for some time. The use of this product in poultry feeds, however, has not been extensive.

Bethke *et al.* (3) reported on experiments in which linseed oil meal was used in chick rations. In their work, chicks fed on rations containing 10% of linseed oil meal grew slowly, exhibited a marked intestinal disorder, and the mortality was high. Ackerson, Blish and Mussehl (1) also conducted feeding trials with chicks using linseed oil meal. These workers concluded that linseed oil meal may be used as one-third of the protein concentrate in conjunction with meat scraps and fish meal where rate of growth is not a primary concern. Christiansen *et al.* (6) substituted 5% of soybean oil meal in chick rations with linseed oil meal and concluded that the linseed oil meal was of no value. Examination of their data would indicate that there was actually an impairment in growth in this experiment. Similarly, Sherwood and Couch (14), reporting on results from feeding trials, stated that old process linseed oil meal, when used as a partial substitute for soybean oil meal, produced poorer growth and required more feed to produce a unit of gain than when linseed oil meal was not present. Concerning the use of linseed oil meal in poultry rations, Titus (16) says that it ranks between cottonseed oil meal and corn gluten meal as a plant protein supplement. This same author points out, however, that if more than 4 to 5% of linseed oil meal is included in the diet it tends to have a laxative effect and for this reason the quantity fed should be restricted to about 2%.

The present experiment was conducted with a view to determining the extent to which the vegetable protein concentrate, linseed oil meal, can be substituted for meat meal in rations for growing chicks.

PROCEDURE

Five groups of about 34 sexed Barred Plymouth Rock chicks (half cockerels and half pullets) per group were used in the experiment. The

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linseed oil meal was included in the rations in such a way as to replace successively larger amounts of meat meal, the protein level being kept constant.

In an attempt to determine the relative efficiency of 2 green feed supplements, when fed in conjunction with varying amounts of linseed oil meal, the experiment was run in duplicate; in one case, 2% cereal grass was used, and, in the other 5% dehydrated alfalfa meal was included.

Newly hatched chicks were weighed individually at the start of the experiment and thereafter at weekly intervals throughout the 10-week feeding period. The birds were started in electrically heated battery brooders and the room temperature, being thermostatically controlled, was kept fairly constant at 80° F. At the end of 5 weeks the birds were moved into growing batteries in another room where no artificial heat was supplied, the environmental temperature being adequate at this time.

The rations in the form of dry mash were kept before the birds at all times and the total feed consumption per group was recorded. Records of the consumption of oyster shell, bone meal and grit which were fed *ad libitum* were also kept. Fresh water was before the birds at all times. The individual feed ingredients were analysed for protein and from these data all rations were formulated to contain approximately 18% protein. The linseed oil meal used in the experiment consisted of a mixture of equal parts of new and old process meals. The rations are presented in Table 1.

TABLE 1.—RATIONS USED IN LINSEED OIL MEAL EXPERIMENTS

Ingredients	Composition of ration									
	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9	Group 10
	%	%	%	%	%	%	%	%	%	%
Ground oat groats	21	21	21	21	21	21	21	21	21	21
Ground wheat	21	21	21	21	21	21	21	21	21	21
Ground yellow corn	21	21	21	21	21	21	21	21	21	21
Buttermilk powder	5	5	5	5	5	5	5	5	5	5
Ground barley	17.25	15.75	14.25	12.75	11.25	14.25	12.75	11.25	9.75	8.25
Meat meal	12	9	6	3	0	12	9	6	3	0
Linseed oil meal	0	4.5	9	13.5	18	0	4.5	9	13.5	18
Cereal grass	2	2	2	2	2	—	—	—	—	—
Dehydrated alfalfa	—	—	—	—	—	5	5	5	5	5
Salt (iodized and manganized)*	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Cod liver oil (fortified)†	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25

* This salt contained 0.02 .02% KI and 2% of $MnSO_4 .4 H_2 O$.

† The cod liver oil contained 3000 I.U. vitamin A and 400 A.O.A.C. units of vitamin D per gram.

The average weekly weights together with the survival data in each group are given in Table 2.

TABLE 2.—AVERAGE WEEKLY WEIGHTS OF CHICKS AND SURVIVAL DATA

——		0 weeks	1 week	2 weeks	3 weeks	4 weeks	5 weeks	6 weeks	7 weeks	8 weeks	9 weeks	10 weeks
Group 1												
No linseed oil meal	C	38.9	59.2	92.2	139.1	220.1	302.3	414.1	539.2	666.9	808.1	913.8
12% meat meal	P	37.6	58.7	96.8	152.3	225.3	324.0	443.0	541.7	673.7	810.5	881.2
	A	38.3	58.9	94.4	145.3	222.6	312.5	427.7	540.3	670.1	809.2	898.5
		34*	32	32	32	32	32	32	32	32	32	32
Group 2												
4.5% linseed oil meal	C	37.3	56.2	81.6	118.3	177.3	255.4	360.0	479.4	612.1	744.7	839.7
9% meat meal	P	36.6	57.8	91.5	140.8	211.1	295.2	409.2	533.1	647.6	764.1	836.9
	A	37.0	56.9	86.1	128.5	192.7	273.5	382.4	504.0	628.2	753.5	838.4
		34	33	33	33	33	33	33	33	33	33	33
Group 3												
9% linseed oil meal	C	36.7	52.7	72.1	97.2	142.8	198.9	259.5	344.1	439.6	502.5	546.8
6% meat meal	P	37.9	58.0	80.6	108.1	149.5	203.6	264.3	349.7	455.9	504.1	624.4
	A	37.2	55.1	76.0	102.5	145.9	201.1	261.8	346.7	447.3	503.3	581.8
		34	33	33	33	32	32	32	32	32	32	31
Group 4												
13.5% linseed oil meal	C	38.1	54.5	74.1	100.4	133.2	163.8	199.2	256.1	341.4	392.3	437.4
3% meat meal	P	37.9	50.5	64.5	78.9	97.9	121.6	148.0	211.1	297.2	343.9	409.7
	A	38.0	52.7	69.8	90.7	116.7	143.8	178.7	238.1	323.7	372.9	426.6
		34	34	33	31	30	29	25	25	25	25	24
Group 5												
18% linseed oil meal	C	37.8	50.6	65.8	82.9	107.9	135.7	160.9	192.1	251.4	305.2	354.5
No meat meal	P	36.9	51.2	62.2	71.5	97.5	109.5	120.4	120.2	134.5	157.0	162.0
	A	37.4	50.9	64.1	77.4	103.8	124.7	146.4	164.5	208.9	268.1	306.4
		34	34	31	26	20	19	14	13	11	8	8

TABLE 2.—AVERAGE WEEKLY WEIGHTS OF CHICKS AND SURVIVAL DATA—*Concluded*

——		0 weeks	1 week	2 weeks	3 weeks	4 weeks	5 weeks	6 weeks	7 weeks	8 weeks	9 weeks	10 weeks
Group 6												
No linseed oil meal	C	37.1	56.6	91.9	141.4	223.8	311.9	451.2	582.2	730.1	866.1	989.8
12% meat meal	P	35.1	55.7	90.2	137.3	212.3	304.1	442.5	544.4	682.1	804.6	907.5
	A	36.1	56.1	91.1	139.4	217.9	307.9	446.7	546.6	705.4	834.4	948.6
		34	32	32	32	31	31	31	31	31	31	30
Group 7												
4.5% linseed oil meal	C	37.2	58.8	89.1	122.6	188.4	264.6	372.8	482.3	593.9	666.0	773.6
9% meat meal	P	37.1	54.3	82.8	118.6	175.3	243.7	344.3	463.5	582.3	703.0	769.9
	A	37.1	56.6	86.1	120.7	182.2	254.5	359.0	473.2	588.3	683.9	771.8
		34	31	31	31	31	31	31	31	31	31	31
Group 8												
9% linseed oil meal	C	36.5	54.8	79.8	114.4	166.7	231.6	334.5	435.8	573.4	659.9	755.2
6% meat meal	P	37.6	55.9	83.0	118.2	172.3	233.0	338.1	441.1	558.9	652.7	745.0
	A	37.4	55.3	82.0	116.3	169.5	232.3	336.3	438.4	566.4	656.4	750.3
		35	33	32	32	32	32	32	32	31	31	31
Group 9												
13.5% linseed oil meal	C	37.5	52.6	67.2	84.3	119.3	156.7	199.9	281.2	357.1	423.8	489.4
3% meat meal	P	37.4	53.7	64.9	83.6	116.8	156.5	196.2	272.8	311.1	354.1	405.2
	A	37.5	53.1	66.2	84.0	118.3	156.6	198.3	277.6	337.2	392.6	453.0
		35	33	32	32	31	31	31	31	30	30	30
Group 10												
18% linseed oil meal	C	38.3	54.6	66.9	86.2	110.1	136.1	162.5	205.5	227.5	253.8	286.1
No meat meal	P	37.3	47.1	57.2	69.7	89.4	127.3	143.7	176.7	190.7	220.4	237.5
	A	37.8	51.0	62.6	76.6	101.0	132.7	154.5	191.6	210.7	239.7	265.6
		35	31	27	25	25	23	20	20	20	19	19

C—Average weight of cockerels in grams. P—Average weight of pullets in grams. A—Average weight of group in grams. *—Number of survivors.

Table 3 indicates the mortality by groups.

TABLE 3.—THE EFFECT OF LINSEED OIL MEAL ON MORTALITY OF CHICKS

Group	Mortality	Group	Mortality
1	0	6	2
2	0	7	0
3	2	8	2
4	10	9	3
5	26	10	12

NOTE—Deaths which occurred during the first week of the experiment are not considered to be due to the ration and therefore are not included in the above mortality tables.

Although the mortality (Table 3) was not excessive until the highest levels of linseed oil meal were reached, many of the birds in the groups fed rations containing 9% of linseed oil meal showed marked symptoms of poor health. In many cases, the beaks became encrusted with feed and deformed, and in practically all birds, the feathers were ruffled and unkempt, presenting a generally unthrifty appearance. When the level of linseed oil meal was raised to 13.5%, the condition was even more aggravated, and in these groups, and the 18% groups, many toe nails were sloughed off, bodies were short and stubby, and all the birds showed signs of severe impairment in health.

The original intention in this experiment was not only to determine the possibility of replacing varying amounts of meat meal by linseed oil meal, but also to compare cereal grass and dehydrated alfalfa as green feed supplements when fed along with linseed oil meal. In view of the drastic reduction in growth (Table 1) and impairment in health when moderately high levels of linseed oil meal are included in the rations, the effects of the green feed supplements are masked and it will merely be considered as one experiment in duplicate. At any rate, the linseed oil meal effect is very marked and essentially the same regardless of the green feed used.

As can be seen in Figure 1, the addition of even 4.5% of linseed oil meal to replace its protein equivalent (N $\times$ 6.25) in meat meal, materially slowed down growth and reduced the maximum weight attained, as compared with the groups receiving no linseed oil meal. When higher levels of linseed oil meal were substituted for meat meal, the growth rate and gains were still more markedly reduced.

The poor response obtained with large amounts of linseed oil meal may possibly be caused by deficiencies of such factors as amino acids, riboflavin, pantothenic acid, vitamin A, or a combination of these and certain other entities. On the other hand, the results may be attributable to a factor or factors in the linseed oil meal causing poor utilization of certain essential elements or directly detrimental to growth and health.

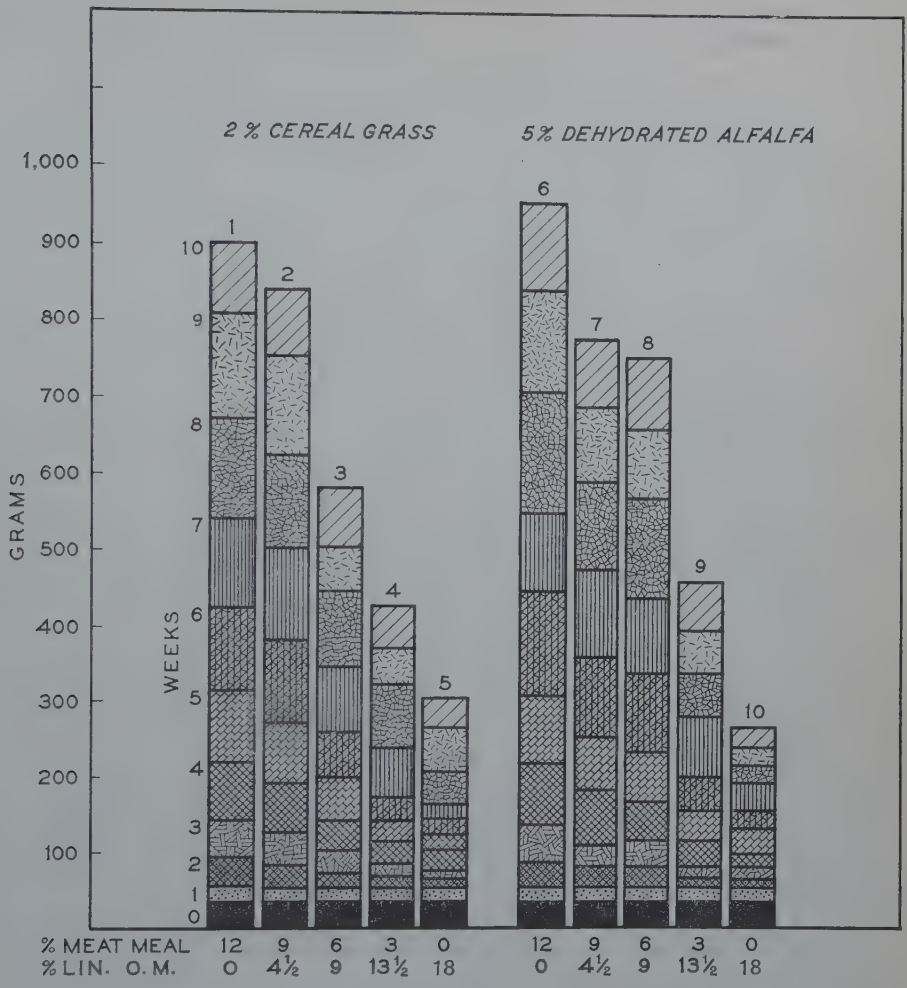

FIGURE 1. The effect of the substitution of linseed oil meal for meat meal on the growth of chicks.

No characteristic deficiency symptoms of any of the above listed essential ration ingredients were noted even in the birds on high levels of linseed oil meal, but nevertheless, consideration of the rations from the deficiency point of view is warranted.

In the groups where most of the meat meal was removed in favour of linseed oil meal, one might think that certain essential amino acids which are not contained in linseed oil meal became a limiting factor in growth. However, as will be noted in Figure 1, there is a decided reduction in growth even when only 3% of meat meal has been replaced (groups 2 and 7), and in this instance it is very unlikely that the amino acids removed would cause such a marked growth reduction.

In addition, linseed oil meal compares favourably in amino acid content, both qualitatively and quantitatively with soybean oil meal according to the results of analysis by Hamilton *et al.* (6). Since soybean oil meal can

replace all of the meat meal in this same ration without material reduction in growth (unpublished data in this department), it is improbable that a deficiency of amino acids is a major cause for the exceedingly poor growth response with high levels of linseed oil meal.

The individual ration ingredients were assayed for riboflavin by the microbiological method of Snell and Strong (15) using acid extraction methods. The results are presented in Table 4.

TABLE 4.—RIBOFLAVIN CONTENT OF THE INGREDIENTS OF THE RATIONS STUDIED

Ingredient	Riboflavin in micrograms per gram	Ingredient	Riboflavin in micrograms per gram
Ground oat groats	2.1	Ground barley	2.0
Ground wheat	1.8	Meat meal	4.1
Ground yellow corn	1.0	Linseed oil meal	2.1
Buttermilk powder	32.5	Cereal grass	16.0
		Dehydrated alfalfa meal	16.0

Using these assay results to compute the riboflavin content of the ration of group 5, containing 18% linseed oil meal, a value of approximately 1600 micrograms per pound is obtained, and for the ration of group 10, also containing 18% linseed oil meal, a value of about 1800 micrograms per pound. Since the ration of group 5, which shows a lower calculated riboflavin content than any of the others, has a riboflavin content in excess of the optimum required for growth as indicated by Heuser *et al.* (10) and Bethke and Record (5), it is justifiable to conclude that riboflavin did not limit growth in any of the groups studied, unless considerable destruction took place after the rations were mixed.

Pantothenic acid determinations were not conducted on the ration ingredients, but computations based upon average assay results of other workers indicated the group 5 ration, with a filtrate factor value of 0.95, as poorest in this regard. However, even this value meets the requirement as outlined by Jukes (12) and, apparently, the poor growth obtained on the high levels of linseed oil meal cannot be attributed to pantothenic acid deficiency in the rations as mixed. The possibility of loss after mixing, however, must be kept in mind here also.

Many papers have been published (Fraps and Kemmerer (8), Heywang and Morgan (11), Bethke *et al.* (4), Baird *et al.* (2), as well as a host of others) to show that the vitamin A in cod liver oil and the vitamin A precursors in other feed ingredients are unstable to varying degrees depending upon the length of time and temperature of storage, the fineness of certain other of the ration constituents, type of storage container, etc. In addition, Dyme *et al.* (7) showed that certain unsaturated fats when heated and fed to rats tended to inactivate the vitamin A in their diets.

There is little doubt, therefore, that some loss of vitamin A did occur in the rations studied. But the vitamin A content of these rations when mixed was considerably higher than the recommended level for growing chicks as indicated by Ringrose and Norris (13) and other workers. In addition, since no signs of xerophthalmia were encountered, and since the growth of control groups 1 and 6 was adequate, it seems unlikely that vitamin A deficiency was a major factor in reducing growth.

The consumption of feed and mineral supplements is presented in Table. 5.

TABLE 5.—CONSUMPTION OF FEED AND MINERALS

Group	Feed	Oyster shell	Bone meal	Grit
	lb.	lb.	lb.	lb.
1	230	3.25	3.75	4.00
2	221	3.25	3.75	3.50
3	204	3.25	3.50	3.50
4	147	3.25	3.25	3.50
5	63	1.75	1.75	2.00
6	207	2.25	3.75	3.50
7	180	2.25	2.25	2.50
8	180	3.25	3.25	3.50
9	178	2.25	2.25	2.50
10	114	2.25	3.25	2.00

As the level of linseed oil meal is increased, the feed consumption seems to decrease, but since figures for total consumption and not weekly consumption of feed are presented (Table 5), no conclusion can be drawn as to palatability. In any case, the health of the birds on the higher levels of linseed was such that any reduction in feed intake was probably due to this factor and not to any undesirable flavour in the feed.

It would seem improbable, therefore, that the decided deceleration in growth, the high mortality, and the extremely unthrifty condition of the birds produced on high levels of linseed oil meal could have been due mainly to deficiencies. But rather, since the reduction in growth was apparent even on levels of 4.5% of linseed oil meal, it would seem necessary to postulate that some factor, detrimental to growth and health of chickens, is present in the linseed oil meal used in these trials.

SUMMARY

An attempt has been made to replace part or all of the meat meal in a growing chick ration with linseed oil meal. It has been found that even 4.5% of linseed oil meal cannot satisfactorily replace its protein equivalent ($N \times 6.25$) in meat meal, in the rations used.

There is an indication that linseed oil meal contains a factor or factors detrimental to the growth and health of chickens.

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SUITABILITY OF SEVERAL SIZES OF AMERICAN ANTHRACITE AND OF BITUMINOUS COAL FOR USE IN BROODER STOVES

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[Received for publication April 21, 1943]

A threatened shortage of the standard fuel for brooder stoves, namely nut size anthracite, made it desirable to determine the merits of certain other sizes of anthracite coal and of bituminous coal, for this purpose. Accordingly 5 identical brooder stoves were set up each in a 10′ × 12′ colony brooder house. The stoves used were Royal No. 6 which are commonly used to brood from 300 to 500 chicks. These were fitted with a 5-inch flue pipe fitted with a manually operated shut-off or key damper. All air leaks in the stoves were plugged with furnace cement and the flap (check) damper below the collar of the stove was fastened in the vertical position. All stoves were run for a period of 9 days on nut size anthracite during the first 2 days of which all thermostats were adjusted to open the check dampers at a temperature of 95° at the edge of the hover. This preliminary period served the purpose of regulating the thermostats, permitting the operator to become acquainted with the idiosyncrasies of the different stoves and obtaining a constant temperature record which would accurately describe the variability in temperature for each stove with the same fuel and under the same conditions of outside temperature. Recording thermographs were used for this purpose. It was actually found that, if the stove producing the most uniform temperature was considered as having zero variability the others exceeded it in variability by 5%, 9%, 11% and 14% which were appreciable deviations. Temperature comparisons for the actual experimental tests were made only for periods following this time of preliminary adjustment. The fuels used in these tests are described in greater detail in the appendix to this paper as well as being referred to under the separate heading for each fuel. A little time was required to become accustomed to the best method of handling the different fuels. The method of operation described herein represents what seemed to be the most satisfactory one for these fuels and stoves as determined by this experience.

METHOD OF OPERATING STOVES WITH DIFFERENT FUELS

The method of operating the stove in which nut size anthracite was used may be considered as standard and will be given in detail. Where any differences of treatment were accorded to the other fuels they will be noted under the separate headings for each fuel.

Nut Size Anthracite

The stove was shaken down at 7:00 a.m. each morning until the first live coals came through the grate. If a dead area was present in any part of the grate the ash was cleared out from underneath with the poker

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to be sure that draft was established over the whole grate area. The ash-pit door remained open with the flue pipe key turned in a vertical position until the fire was burning freely when the door was closed, the stove filled to the top with fuel and the pipe key turned to three-quarters closed. Since the addition of a large body of cold fuel has a retarding effect upon the fire, in cold weather it is preferable either to allow the fuel to burn freely for a longer period before adding the coal and checking, or to add only two-thirds capacity of coal filling up completely at a later tending. At 5:00 p.m. and 9:30 p.m. the stoves were again shaken down and filled to the top with fuel. The stove size anthractite was handled in the same way as the nut size.

Pea and Stove Size Anthracite (Equal Proportions)

The stove was managed in the same way as was done for the nut anthracite. The 2 sizes could be mixed 50 : 50 or fed in layers with stove first followed by pea then stove and so on, this feeding in layers proving to be a slightly more satisfactory method of feeding on the average.

Pea Size Anthracite

This fuel, because of its fineness, lies less open in the stove and for that reason requires an added amount of draft. This must be accomplished by leaving the key in the flue pipe in the open position at all times and by very thorough shaking and loosening up of the fuel at each attention. The grate should be well shaken and the coal stirred up thoroughly with a heavy poker to be sure all ash is loosened to settle out after which an additional light shake is required to clear the grate. For the same reason it is advisable to add only half the fuel required to fill the stove at one filling so as to avoid retarding the fire too much. In a stove having more draft than that available in this instance pea size anthracite should be a more useful size.

Nut Size Bituminous Coal

It should be pointed out that the bituminous coal used in this test proved to have characteristics, on analysis, which indicated it not to be the most desirable type available for this purpose. For example this sample was a true "gas coal" with high volatile matter content and high caking and swelling characteristics. Had a low or medium volatile (smokeless) bituminous coal with more moderate caking and swelling characteristics been used a more satisfactory result might have been expected. In actual operation the good caking quality of this fuel proved to be its greatest drawback for use in this type of stove. If the caked or coked mass was not broken down thoroughly soon after formation, bridging was the result and when the fuel next to the grate was consumed the fire would go out. If after the coke was formed it was thoroughly broken down however, no trouble was experienced in keeping the fire alive during the night. The procedure found to be most satisfactory was as follows. The stove was shaken down at 7:00 a.m. and the caked mass of fuel thoroughly broken up with a heavy poker. The ash-pit door and flue pipe key were left open until the fuel burned up freely when the stove was filled up with fresh fuel and checked. The same procedure was followed at 5:00 p.m. and again

at 9:30 p.m. at night. Complete breaking up of the coke formed mass is essential and cannot be too greatly stressed since the fire died out during the night on every occasion during the preliminary period when this was not done.

Caution—Because of the volatile nature of most bituminous coals the fire should never be left unattended while the drafts are fully on.

RESULTS

It was thought that the most satisfactory appraisal of the suitability of the fuels could be made from the most critical phase of the test, namely under the most severe weather conditions encountered. The table following shows the pertinent data for the most severe condition expressed as the minimum temperatures recorded during the coldest period.

TABLE 1.—MINIMUM TEMPERATURES OBSERVED UNDER BROODING HOVER*

Fuel	Temperature under hover		
	10″ from stove	15″ from stove	Edge of hover (20″)
	°F.	°F.	°F.
Nut size anthracite	126	111	76
Pea and stove size anthracite (50:50 mix)	130	116	78
Stove size anthracite	95	90	59
Pea size anthracite	94	89	58
Nut size bituminous coal	80	72	42

* Outside temperature 12° F. below zero. Wind velocity 10 miles per hour.

In attempting to assay the results shown in the above table the most important single consideration is the fact that an outside temperature of 12° F. below zero plus a wind of 10 miles per hour represents extreme conditions for brooding of chicks even in very well built and insulated buildings. Even under the existing conditions a reasonable temperature was maintained with all of the anthracite fuels regardless of size. It should be realized that the low temperatures shown above were only for 2 to 3 hours duration at the most followed by a quick recovery when the stove was opened up in the morning. While higher temperatures are desirable a temeprature of 95° at a distance of 10″ from the stove allows the chicks to find a reasonable temperature at the middle of the hover. The only time when danger would be involved would be with chicks just out of the incubator at these temperatures. However, chicks were actually being brooded at this time in temperatures as low as 71° at the edge of the hover very satisfactorily and with no mortality. In keeping with usual practice a ring of galvanized sheet iron was set up two feet away from the hover to keep the chicks from wandering away from the source of heat during the first few days. If chicks came fresh from the incubator this ring could be closed in to within 2 to 4″ of the hover thus keeping the chicks under the hover as well as confining the heat which escapes under the edge of the

hover and maintaining a higher temperature. In all cases attention to the stove once during the night under such critical temperature conditions would have prevented such a slump in temperature.

The temperature experienced with the bituminous coal was too low for successful brooding excepting with chicks 2 to 3 weeks old. In this instance, attention to the stove during the night would be necessary to maintain a sufficiently high temperature. On the night before the one during which the temperatures shown in the table were recorded the lowest outside temperature was 7° above zero with a wind at 8 miles per hour. The temperatures under the hover of the bituminous stove were 124°, 109° and 72° (stated in the same order as in the above table) at their lowest level. As will be noted when the fuels are considered in more detail, the bituminous coal used is not considered the best type available for the purpose.

Variability in temperature is of some importance although as long as temperatures do not drop too low variability is not of serious consideration. Too high temperatures can also be injurious but with thermostatic control excessive temperatures should not occur and if they do the chicks can adjust themselves to the proper temperature by moving away from the stove as they will do. When allowance is made for the variability characteristic of each stove when burning the same fuel, nut size anthracite gave the most consistent temperatures followed closely by the mixture of pea and stove size anthracite and the stove size anthracite alone. The pea size anthracite was considerably more variable than those just mentioned although as experience in the proper method of handling of this fuel was gained variability of temperature dropped considerably. Variability was very great with the bituminous coal and probably could only be reduced by more frequent attention to the stove.

One additional factor should be taken into account in considering the efficacy of the temperatures recorded in the above table, a factor which relates to the degree of comfort of the chick under any recorded degree of temperature. It is an undisputed fact that radiant heat plays a large part in inducing increased body temperature as for example in the case of direct sunshine. Since only a small proportion of the radiant heat from the stoves would be registered by mercury thermometers an additional and appreciable amount of radiant heat would be available to the birds and consequently their degree of comfort would actually be greater than the temperature would indicate.

Suitability of Bituminous Coal for Small Stoves

Since it was felt that the large fuel capacity of the brooder stoves used in these tests made very favourable conditions for maintaining constancy of temperature over long periods without frequent attention to the stove it was decided to use the bituminous coal in a smaller stove viz. one of only half the rated chick capacity (No. 19 Buckeye). With the same treatment as that accorded to the nut size bituminous coal in the larger stove similar temperatures were maintained under almost identical conditions of outside temperature and wind velocity.

DISCUSSION

It is apparent from these findings that, of the fuels tested, nut size anthracite was the most suitable for brooder stoves giving entirely satisfactory performance under extremely unfavourable conditions. Obviously, therefore, if this fuel is available it should be used. When only other sizes of anthracite are available a combination of equal parts of pea and stove size, fired as directed in this paper, should give almost as great satisfaction. Stove size anthracite alone is somewhat less suitable than those mentioned and pea size anthracite alone the least satisfactory size but quite usable if the directions given herein are followed.

In the event that anthracite coal is not available bituminous coal can be satisfactorily used. The type used in these tests, though not best suited to this kind of work, could be used with satisfaction with an ordinary amount of attention under moderate weather conditions such as maintain during March and April brooding in most sections of Canada. For cold weather brooding or in uninsulated or poorly built houses, attention to the stove once during the early morning (at 2:00 or 3:00 a.m. for example) would be necessary to brood satisfactorily. Since bituminous coals vary widely in chemical, physical and burning characteristics, it is obvious that some would be better suited than others for this purpose and might even approach anthracite in this regard. Since each type has its own definite characteristics it is necessary to test out the type which is going to be used to determine the best method of handling it before trusting chicks to its care.

All of the fuels used in these tests would be satisfactory in well built, insulated houses or under moderate conditions of outside temperature and wind velocity.

SUMMARY

Three different sizes of anthracite coal were used in a No. 6 Royal brooder stove viz. pea, nut and stove. A combination of equal parts of pea and stove size anthracite was also used. All three sizes and the combination were found to be satisfactory for the purpose when tested under very severe conditions of brooding namely minus 12° F. with a wind of 10 miles per hour in a 10′ × 12′ colony house with one-third cotton front and without straw loft. The nut size was found to be most satisfactory followed closely by the combination of pea and stove size and the stove size alone. The pea size anthracite was not as satisfactory but sufficiently so for ordinary brooding conditions when handled as suggested herein. For March or later brooding all these sizes would be quite satisfactory.

A sample of nut size bituminous coal was not as satisfactory as any of the anthracite sizes to which reference has just been made.

With attention once during the night, and even without this additional attention under milder weather conditions such as pertain in March and April or much earlier than this in other latitudes, the bituminous coal would have been satisfactory. Since the bituminous coal used was of a type which would be most difficult to use for this purpose it follows that many bituminous coals should be more satisfactory than evidenced by this test. This fuel when used in a smaller stove of half the chick capacity was equally satisfactory.

APPENDIX TABLE 1

CHARACTERISTICS OF FUELS USED

Item	Kind of coal	American anthracite				Bituminous*
	Trade size used	Nut size	Pea-stove mix	Stove size	Pea size	Nut size†
	Approximate size	$\frac{3}{4}'' \times 1\frac{1}{2}''$	$\frac{1}{2}'' \times 2\frac{1}{2}''$	$1\frac{1}{2}'' \times 2\frac{1}{2}''$	$\frac{1}{2}'' \times \frac{3}{4}''$	$\frac{3}{4}'' \times 1\frac{1}{2}''$
	Column No.	1	2	3	4	5
1. Sample mark		Ex. Farm 4	‡	Ex. Farm 2	Ex. Farm 3	Ex. Farm 1
2. Proximate analysis, as received basis:						
(a) Moisture	%	2.2	3.5	3.5	3.5	1.5
(b) Ash	%	11.2	12.1	10.6	13.6	8.6
(c) Volatile matter	%	6.2	5.0	4.4	5.6	36.3
(d) Fixed carbon (by difference)	%	80.4	79.4	81.5	77.3	53.6
3. Ultimate analysis, as received basis:						
(a) Sulphur	%	0.9	0.8	0.8	0.8	3.9
4. Calorific value:						
(a) As fired, gross value	B.T.U./lb.	12,960	12,460	12,680	12,240	13,680
(b) Dry, gross value	B.T.U./lb.	13,250	12,910	13,130	12,690	13,880
5. Caking properties as judged by "coke button"		Non-caking	Non-caking	Non-caking	Non-caking	Good
6. Swelling index— Per cent swelling × 100 / Per cent dry V.M. at 600° C.		—	—	—	—	1,370
7. Ash fusibility:						
(a) Initial deformation temperature	°F.	2,820	2,685	2,550	2,820	1,930
(b) Softening point or fusion temp.	°F.	2,850+	2,775	2,700	2,850+	2,030
(c) Fluid temperature of melting point.	°F.	2,850+	2,850+	2,840	2,850+	2,120
8. Screen analysis, round hole screen openings:§						A / B
(a) $2\frac{7}{16}''$ to $3\frac{1}{4}''$ (Egg)	%	—	6.1	12.2	—	20.2 / —
(b) $1\frac{7}{8}''$ to $2\frac{7}{16}''$ (Stove)	%	3.5	39.6	79.1	—	45.4 / —
(c) $\frac{13}{16}''$ to $1\frac{7}{8}''$ (Nut)	%	69.7	7.7	7.7	7.8	27.0 / 100.0
(d) $\frac{9}{16}''$ to $\frac{13}{16}''$ (Pea)	%	8.6	33.9		67.6	2.2 / —
(e) $\frac{5}{16}''$ to $\frac{9}{16}''$ (Buckwheat No. 1)	%	6.5	10.0		19.7	/ —
(f) $\frac{3}{16}''$ to $\frac{5}{16}''$ (Buckwheat No. 2)	%	3.9	0.8	1.0	1.4	5.2 / —
(g) $\frac{3}{32}''$ to $\frac{3}{16}''$ (Buckwheat No. 3)	%	3.9	0.8		1.4	/ —
(h) Through $\frac{3}{32}''$ (fine screenings)	%	3.9	1.1		2.1	/ —

* A true "gas coal" with high volatile matter content and high caking and swelling characteristics, not considered the best bituminous coal available for the purpose. Had a low (smokeless) or medium, volatile bituminous coal with less pronounced caking and swelling properties been used a better result might have obtained.

† Because of the friable nature of bituminous coal, it is not prepared to as rigid size specifications as are anthracites. A quantity of this bituminous coal was bought in screened lump size which had a screen analysis as shown in column 5A. That part of this coal which conformed to anthracite nut size was used in the test as shown in column 5B.

‡ Data given hereunder are the calculated averages from columns 3 and 4 for a mixture of pea and stove sizes in equal proportions.

§ Standard anthracite sizing specifications of the (American) Anthracite Institute allow a maximum oversize of 5% for egg, 7½% for stove and nut, 10% for pea and buckwheat; and undersize limits of 7½ to 15% for egg, 7½ to 12½% for stove, 5 to 10% for nut, 7½ to 15% for pea and buckwheat.

INCREASE IN QUANTITY, GRADE AND RETURNS FROM PEACHES AS THEY APPROACH OPTIMUM MATURITY

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[Received for publication March 24, 1943]

It is quite generally recognized among peach growers that there is a very rapid increase in size of fruit during the last few days before picking. In the experiments here reported the purpose has been to measure accurately the increase in size, the improvement in grade, and the added monetary returns from the crop when the fruit is left on the trees to the optimum maturity condition in preference to picking at less mature stages. The work was begun in 1938 but owing to inadequate records on stage of maturity, the data for that year are not included in this paper. A record of the investigations of the succeeding 4 years, 1939-42, is given at this time.

REVIEW OF LITERATURE

Several investigators have reported on size increase in peaches immediately before picking time. Coe (1) of Utah measured fruits of various pickings of Elberta, Early Elberta and J. H. Hale for several years. In a typical test with Elberta in 1932 he found that the increase in calculated volume in the last week before the optimum maturity stage was 25.2%. McMunn and Dorsey (3) of Illinois have reported a 24.4% increase in volume for Elberta during the same period and a change from 47.8% of the crop above $2\frac{1}{4}$ inch size to 93.7%. More recently Fisher and Britton (2) of the Summerland, B.C. Station reported an average increase in volume of 28.4% for the varieties Rochester, Vedette and Veteran during the final week before optimum maturity.

MATERIALS AND METHODS

About a fortnight before the probable date of first picking a typical tree of each variety was selected and on it 50 unblemished fruits of near average size were marked with numbered tags. That day and every second day thereafter to the soft ripe stage or until the fall of the fruit, maximum cheek and suture diameters were taken with steel calipers to the nearest millimetre. At the same time records of ground colour on the shaded side were taken for every peach with reference to a colour chart (Figure 1).

Colour 2 on the chart, a colour obtained immediately after the disappearance of the green ground colour, was considered the optimum maturity stage for Veteran, Golden Jubilee, and South Haven. For Elberta optimum maturity stage was taken as being slightly (1 to 2 days) before Colour 2 (2-), i.e., while a slight greenish tint was still present. Peaches of all varieties picked at Colour 1 ripened without shrivelling but with inferior quality. Peaches at Colour 2 stage were still quite hard, would stand handling and distant shipment and, held at room temperature,

[1] Chief in Research.

were not ripe enough for eating for two or three days. At Colour 3 the fruit was definitely soft and suitable for local markets only.

Approximate weights of individual tagged fruits were obtained from graphs of mean diameter and weight using 25 to 50 peaches picked at similar stages of maturity.

RESULTS

For the ground colour to change from Colour 1 to Colour 2 took 4 to 5 days, and from Colour 2 to Colour 3 took 3 to 5 days. In Table 1 figures are given for the arbitrary times of 7 and 4 days before optimum maturity and are based on 100 tons and $100 seven days before optimum maturity

TABLE 1.—INCREASE IN QUANTITY, GRADE AND RETURNS FROM PEACHES AS THEY APPROACH OPTIMUM MATURITY*

——	No. 1 Grade	No. 2 Grade	Tonnage	Gross† Returns
Veteran, Horticultural Experiment Station, 1939-42				
7 days before optimum maturity	73	27	100	100
4 days before optimum maturity	91	19	110	114
Optimum maturity	113	7	120	130
Elberta, Horticultural Experiment				
——	Select Grade	No. 1 Grade	Tonnage	Gross† Returns
Elberta, Horticultural Experiment Station, 1939-42				
7 days before optimum maturity	22	78	100	100
4 days before optimum maturity	55	54	109	109
Optimum maturity	84	34	118	118
——	Select and No. 1 Grades	No. 2 Grade	Tonnage	Gross† Returns
Golden Jubilee, L. E. Hipple Farm, 1941				
7 days before optimum maturity	73	27	100	100
4 days before optimum maturity	107	10	117	125
Optimum maturity	141	0	141	156
——	Select Grade	No. 1 Grade	Tonnage	Gross† Returns
South Haven, G. B. Pfrimmer Farm, 1942				
7 days before optimum maturity	38	62	100	100
4 days before optimum maturity	79	28	107	107
Optimum maturity	106	17	123	123

* Figures on the basis of 100 tons and $100 seven days before optimum maturity.
† Minus cost of containers.

FIGURE 1. Reproduction of ground colour maturity chart for peaches.
Colour 1. Maerz and Paul. Dictionary of Color, 19J1.
Colour 2. Horticultural Colour Standards, 601/2.
Colour 3. Maerz and Paul. Dictionary of Color, 10J2.

The gross returns are based on prices of $37 per ton for Select and No. 1 peaches and $24 per ton for No. 2 grade (Select*, $2\frac{1}{2}''$ and up; No. 1, $2\frac{1}{8}''$ to $2\frac{1}{2}''$; No. 2, 1 $\frac{7}{8}''$–$2\frac{1}{8}''$). These are average shipping point prices over several seasons for peaches sold in baskets. As it is unusual for Ontario growers to obtain a higher price for Select than for No. 1 size these grades were calculated at the same price.

In the 7 days before optimum maturity was reached the crop increased in tonnage from 18% in Elberta to 41% in Golden Jubilee. The latter relatively high figure might be higher than an average for several seasons because of particularly favourable conditions during the ripening season of this variety in 1941. However, this same variety was used in the preliminary work at Vineland in 1938 and in this year also there was a very rapid increase in size.

The increase in percentage of the higher grades as the fruit approaches maturity is even more striking than the tonnage increase. When it means the passing of all or a large porportion of the lower priced No. 2 peaches into the No. 1 Grade, as in Veteran and Golden Jubilee, the rate of increase in gross returns is boosted above the rate of tonnage increase.

Peaches continue to increase in size up to the Colour 3 stage. Four days after optimum maturity the increase ranged from 7 to 10%, enough to interest the grower who is picking for local or roadside markets and can therefore get such fruit to the consumers in good condition.

In addition to size and grade increase as the fruit approaches optimum maturity there is also a rapid increase in red colour on the exposed cheek. Though no measurements were taken in the course of these experiments the change in red colour was quite noticeable and is undoubtedly of considerable value in merchandising the product.

The danger of loss of fruit by dropping is not very great up to the optimum maturity stage, Colour 2- for Elberta and 2 for the other varieties. In 1941 twelve pounds of Elberta peaches, less mature than 2- colour, dropped from a 10-year old tree, mostly in one night, but the wind was unusually severe, reaching a peak of 27 miles per hour. With the Elberta variety, because of its tendency to drop rather readily, it appears to be advisable to keep the fruits picked so closely that none of them pass No. 2 in ground colour. Mature fruits of the other varieties hung to the tree very well even up to Colour 3 stage.

DISCUSSION

Data just presented show very definitely gains in yield and value from leaving peaches on the tree as long as possible. Unfortunately it is not possible to grade, pack and ship soft ripe peaches, and some tonnage will have to be sacrificed if the peaches are to be handled without excessive bruising. However, peaches picked at or near the time of the disappearance of the green in the ground colour are still very firm and with care in packing and shipping will carry as great distances as is required for economical marketing and should give consumer satisfaction. Peaches picked previous to this stage ripen with inferior quality.

*For 1943 the minimum size for Select grade has been lowered to $2\frac{3}{8}''$.

Under conditions where there is a proportion of No. 2 peaches the gain by leaving the fruit on the tree as long as possible may be very considerable. A grower stands to profit both through increased tonnage and higher unit prices for the fruit, the latter due to a larger proportion of the crop coming into the higher priced No. 1 grade. The above considerations apply equally well to growers who have a special market for peaches of Select size and who can therefore get a price higher than is obtainable for No. 1 fruits.

SUMMARY

Over a 4-year period Veteran and Elberta peaches increased in tonnage 20 and 18%, respectively, during the week before the stage of optimum maturity (at or near the time of disappearance of the green in ground colour). During this period in 1941 Golden Jubilee increased 41% and in 1942 South Haven increased 23%. The relative improvement in grade was even greater than the tonnage increase. When No. 2 peaches were present but passing into No. 1 size grade with fuller maturity returns were increased in proportion to the differential in price between the two grades. Except under wind storm conditions the loss from dropping before the optimum maturity stage was of no consequence.

ACKNOWLEDGMENTS

The author wishes to express his thanks to the following students who took most of the field measurements: J. Child, R. Louis, J. Cass, C. Hipple, D. Ross and E. Gaertner.

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BOOK REVIEWS

GARDENING FOR GOOD EATING. By Helen Morgenthau Fox. Published by MacMillan Company of Canada, Limited, Toronto. Price $2.75.

Popular books on gardening which attempt to cover a wide field of information as well as a wide geographical range are in general not of much specific value for the individual gardener. He usually finds it much safer to depend upon local bulletins and pamphlets by his nearest Department of Agriculture.

The book written by Mrs. Fox belongs in a different category, however. It is really gardening "literature." It does not attempt to give more than three or four brief chapters on the soil, culture, and insect and disease control. The material in these chapters is excellent but should be supplemented by local information.

The reason that her book should find a place in the gardener's library is that it tells him a great many things that his local authorities know very little about. Chapters on forgotten vegetables; edible plants from field, marsh, and forest; salads in variety; native American vegetables; the herb patch; home-grown teas; and vegetables old and new, open vistas of interesting amateur experiments which will serve to relieve the monotony of the ordinary radish, lettuce and turnip patch. Here is a chance to produce something that will excite your neighbour's envy; if you can't beat him on the size of your pumpkins or the smoothness of your tomatoes, present him with a basket of rhubarb chard or invite him in for a sorrel turnover. You won't have to go hunting for your cook book, for the recipes are all printed along with the descriptions of the vegetables and how to grow them. In fact there are many tempting recipes for the old favourites.

There is a chapter on right eating with a discussion on vitamins and minerals, and another chapter on preserving and storing the winter supply.

The book is very well printed, and illustrated with excellent pen and ink drawings by Louise Mansfield. Taken all in all, *Gardening for Good Eating* deserves a place on your shelf of garden literature.

H. L. T.

FOOD FOR THOUGHT. By Herman Frederick Willkie and Paul John Kolachov, Joseph E. Seagram & Sons, Inc., Louisville, Kentucky. 209 pages, illustrated, Published by Indiana Farm Bureau, Inc., Indianapolis, Indiana, 1942. Price $2.00.

This book is a review of recent spectacular progress in solving the power alcohol problem. Radical and far reaching suggestions are made by the authors for the utilization of farm products for the production of ethyl alcohol—farm motor fuel as a means of solving the agricultural problem. They consider fundamentally unsound any scheme in which the raw material is purchased from the farmer and the blend of alcohol and gasoline sold back to him at a few cents more per gallon than ordinary motor fuel.

Prices of farm products fluctuate so frequently and so widely that an alcohol industry has difficulty in grossing a steady profit; the cost of blending is dependent upon the sale of the by-product feed to the farmers.

They propose to manufacture 190-proof alcohol in community distilleries—an extension of the antique practice of community milling—to be used as motor fuel in the farmers tractors. The International Harvester Company has manufactured tractors and trucks for use in the Philippines which run on 190-proof alcohol and are not materially different from those operating in this country.

The farmers would bring their surplus farm products and unmarketable accumulations to the distilleries and would take away ethyl alcohol, which had been rendered unfit for use as a beverage, and the stillage (residue from alcohol manufacture) in amounts proportional to the raw material brought in, the latter to be used as feed or fertilizer. In this way, everything returns to the farm and soil fertility is conserved. The distilleries could be financed by communities and farmers' co-operatives, or by a government loan—not a subsidy—that would be constructive and eventually pay for itself.

This scheme is highly speculative and its practicability has still to be demonstrated. The authors believe that manufacturers of agricultural implements, farmers' organizations and scientists well informed on fermentation and distillation processes, should give some thought to the project and consider how it can be incorporated in the post-war agricultural program.

Research on the production of alcohol, being conducted in the laboratories of Joseph E. Seagram and Sons, Inc., Louisville, Kentucky, is also reviewed in relation to the design of the community distillery. They have revolutionized plant design and operation, having developed a continuous cooking and washing system for cereal grains. The perfection of a continuous fermentation process might make possible the designing of a mobile distillery to operate in the farmyard.

W. D. McF.

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